

Experimental and Research Station,
Nursery & Market Garden Industries'
- - Development Society, Limited. - -
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Introduction.

THE Experimental and Research Station was inaugurated in 1914 under the auspices of the Nursery and Market Industries Development Society. From small beginnings the Station has developed a fully equipped laboratory, housing a scientific staff capable of dealing with the problems which may be submitted by growers from time to time. In addition there are six cucumbers houses, twelve tomato houses and two glasshouses for entomological work.

In 1927 a plot of land, some $1\frac{2}{3}$ acres in extent, adjoining the Station property on the north side, was purchased for the purpose of erecting a Director's house, and to provide space for additional glasshouses. The dwelling house was completed during the current year and it is hoped that funds may be forthcoming in the near future to permit the erection of glasshouses where crops other than the cucumber and the tomato can be grown. When this is done the Station will be in a position to experiment with such crops as grapes, roses, carnations, ferns, melons and mushrooms as well as certain decorative pot plants.

Anyone able and willing to finance this project would be a public benefactor, for the Station, started to benefit a local industry, now serves the nation, and the need for experiments with all glasshouse plants is becoming increasingly greater each year.

Membership of the Society, under whose auspices the experiments are conducted, is open to all growers and interested persons and subscriptions are payable at the rate of two guineas for each acre of glass cultivated by the subscriber. In return members receive future publications and any advice which is available. Members are constantly being enrolled, but many more are needed, both to provide additional funds for research and to obtain complete co-operation in controlling

the various pests and diseases common to glasshouse plants. Serious outbreaks over a wide area must be fought by all growers; isolated attacks are bound to fail.

Evening Discussions.

The evening lectures for nursery owners and employees begun in 1925, at the request of the workers are continued during the present year, the subjects being chosen :—

1927.

Nov. 29th.—The Manuring of Tomatoes.

Dec. 13th.—Open night.

1928.

Jan. 10th.—Humidity of Glasshouses.

Jan. 24th.—Peculiarities of the Life-Histories of Animals in Glasshouses.

Feb. 7th.—The Improvement of Varieties.

Feb. 21st.—Construction and Repair of Glasshouses.

Mar. 6th.—The Importance of good Grading and good Packing.

Mar. 20th.—Open night.

The meetings were generally well attended, especially by employees. Through the generosity of the Lea Valley Growers' Association light refreshments were served during the interval between the opening speeches and the general discussion.

It is hoped that nursery owners will attend these discussions more frequently in the future, for the efforts to interest the workers in the general principles of horticulture and the latest discoveries of applied science must ultimately increase the efficiency of the industry.

Lectures and Exhibits.

Invitations to lecture on glasshouse problems have been received from organised bodies of nurserymen in many parts of the country and have been undertaken by the Director and the Entomologist. In general, the lectures have been well attended and stimulating discussions followed in every case. An Exhibit set up at the Royal Horticultural Society's Spring Show at Chelsea caused many enquiries.

Grants.

The Empire Marketing Board has generously provided a capital grant of £1,600 for the erection of four new glasshouses and a maintenance grant of £1,660 a year in support of investigations of suitable control measures for the Red Spider and allied mites, Tomato Mildew and Mosaic Disease, together with the cultivation and distribution of the White Fly parasite, *Encarsia formosa*. The Lea Valley Growers' Association have also granted the sum of £200 per year for the purpose of studying the activities of the Red Spider Mite in commercial nurseries.

Our sincere thanks are tendered to these bodies for their generous assistance.

Current Investigations.

Manurial and Crop management trials with tomatoes have been continued.

The stable manure experiments of 1926 and 1927 have been continued in other houses during 1928. The soil down to pasture for many years was given 15 and 30 tons of stable manure per acre in different plots and as before no benefit was seen from increasing the dressing beyond 15 tons per acre. It is difficult to understand why many growers continue to use much heavier dressings without themselves testing the effect of relatively small applications.

Experiments concerning the substitution for stable manure of wheat straw or bean straw, and the additions of these materials in excess of normal treatment were conducted in houses 7 to 9. There were indications that stable manure can be replaced in this way with advantage during at least a year.

Increased crops were obtained by treating the soil with formaldehyde and taking a crop of tulips before the normal tomato crop. Steps are being taken in 1929 to see if the crop increase is due either to the treatment with formaldehyde or the decomposition of tulip roots or both.

The effect of lime was tested in two new houses in which the soil contains only traces of carbonates. Plots without lime produced a heavier crop than the limed plots.

The effect of regular applications of a top dressing fertilizer at the rate of two ounces per square yard was compared with that from one ounce per square yard. From the results it seems that the heavier dressing was beneficial.

Instead of the watering experiments of 1926 and 1927 when attempts were made to determine the effect of applying more and less water per acre than is usually given, new experiments were designed to test the effect of different methods of watering. On certain plots, water was applied by a hose in the usual fashion; in others, it was allowed to percolate slowly through twelve inch pots sunk in the ground, in others it was given through pipes buried eighteen inches below the surface; lastly, it was applied to trenches, six inches deep in which plants were set out. There were indications that the last method may ultimately prove to be the best, for by collecting the water during overhead damping the trenches kept reasonably moist, and so prevented the need for very early watering, which on the Station soil tends to produce a soft growth.

The variety trials of previous years showed that Up-to-date and Stirling Castle are highly resistant to *Cladosporium fulvum*, but are not among the best fruiting varieties. They were crossed with E.S.1 in 1927 and the F1 generations grown in 1928 also proved resistant. Two other varieties, Maincrop and Satisfaction also showed some resistance to "Mildew."

The investigations of the temperature requirements of the tomato were commenced this year, in chambers fitted with thermostatic control. Minimum night temperatures of 57°, 62° and 70°F. were maintained in different chambers, with the result that the crop grown at a minimum temperature of 62°F. was 28 per cent. greater than that at 70°F. and 21 per cent. greater than that at 57°F. These results are considered important, as they confirm previous observations both at the Station and in nurseries.

Soil temperatures of 73°F. and 68°F. were maintained during March, April and May by means of electrically heated wires buried 15 inches below the soil surface. A measurable increase was obtained at the highest temperature but the present high cost of electricity is likely to prevent the adoption of this form of heating on a commercial scale.

Cucumber experiments to study the base, or soil on which the bed is placed, ended in 1927. It was shewn, that, if the base consists of gravel or a similar open material, satisfactory crops can be obtained each year by the simple device of flooding heavily with water. If the base consists of heavy loam, it is necessary to steam it each year to destroy the contaminations washed down into it from the bed above during the season of growth. The new experiments relate to the mechanical condition of the bed. Wheat straw, bean straw, clinkers and lump chalk were incorporated with the beds on different plots. The beneficial effect of an open spongy bed was seen in each case. The addition of lump chalk was harmful and gave rise to a mass of slimy material which choked the bed.

Cucumbers were grown under glass which transmits the ultra-violet rays of the sun, in the south half of a house fitted with ordinary glass, in the other half. The crop was 25 per cent. greater in the south half of the house.

The Red Spider investigations have been continued. An advance has been made in the knowledge of the winter habits of the Red Spider Mite in its reaction to heat and light. In winter, the mite seeks situations at a temperature of about 50°F., and prefers a lower rather than a higher temperature. In the presence of sunlight the mite becomes active at a low temperature, and it will overcome its preference for such a temperature to reach sunlight.

Emulsions of comparatively heavy and pure petroleums have been of great use to the growers of tomatoes and cucumbers in checking the pest during the summer. It has been established experimentally that when plants are well sprayed they become immune from attacks of the mite during at least eleven days after application.

Care is necessary in regulating the supply of moisture to the plant, especially to tomatoes when they have been sprayed with these emulsions, which tend to conserve moisture at the leaf surface.

The examination of volatile compounds for use in controlling the Red Spider Mite on growing crops has been continued throughout the year. In most cases plants were seriously injured

by the concentrations necessary to ensure destruction of the Spider. Several substances which were shown in 1927 to cause a high percentage mortality of the Mite when used in fairly low concentrations (*i.e.* 1-4 ozs. per cubic foot), in particular dichloro-aniline and trichloraniline were tried under varying conditions but in no case was a control effected without serious damage to plants.

Investigations regarding the use of oils emulsified with soap have been commenced and methods devised whereby stock emulsions showing stability over long periods can be made by a simple process. In addition to refined petroleum, certain vegetable oils yield an effective control of the Mite without damage to plants.

The Chalcid parasite, *Encarsia formosa*, of White Fly has been bred and distributed to growers from the glasshouse specially constructed for this purpose. A rough estimate gives the figure for the number of parasitised scales of White Fly distributed as 287,000.

Reports from the recipients of the parasite shew that in 27 cases complete control of the White Fly was obtained, and in other 24 cases partial control was obtained from the consignments distributed from February to the end of June. From consignments distributed after July last only partial control was obtained. Failure to establish the parasite on nurseries occurred in only two cases, both in the north of England, using small numbers of parasitised scales. On large nurseries, where partial control was obtained, the percentage of parasitism varied from 30 per cent. to 90 per cent. in September, the lower percentage being met with in leaky and therefore cooler situations.

Last year the Chrysanthemum Midge, *Diarthronomyia hypogaea* made its appearance in this country, and through the strong co-operation, in carrying out control measures, of growers whose Chrysanthemums were infected last year, especially in regard to the cleaning of undergrowth from the plants before taking cuttings, there is now no sign of infection by the midge in the nurseries which have been under the immediate supervision of the Station.

The temperature and humidity of glasshouse atmospheres have been studied in relation to their effect upon infection by *Cladosporium fulvum* and its further development upon the plant. At the optimum temperature of 72°F. the disease can be controlled only by keeping the humidity below 70 per cent. saturation. At humidities of 70 per cent. and over, the disease spreads rapidly unless the temperature is held below 60°F. Records show that the humidity of glasshouses usually exceeds 90 per cent. during several hours each night ; and it is suggested that these conditions are largely responsible for tomato mildew.

An attempt has been made to discover a method of checking the development of Verticillium wilt by applications of solutions to the roots of infected plants. A mixture of mercuric chloride and sodium nitrate has given the best results so far.

The investigation of mosaic disease has been continued along the lines of systematic roguing in an attempt to prepare stocks of seed of tomato and cucumber free from the virus.

Nitrate determinations on the soil of some of the experimental plots were continued during the winter 1927-1928 until May, 1928. The main conclusions already reported were confirmed. In addition it has been found that fluctuations in the amount of nitrate are greatest in soils which show high concentrations of nitrate nitrogen. In old soils, the accumulation of nitrates during the fallow season commences in January and continues till after planting. Plots on the west side of a house are richer in nitrates than those on the east side. The fall in nitrate concentration which occurs in April or early May may be associated with the leaching consequent upon watering ; this point is to be investigated.

Experiments have been conducted to determine the effect of copper sulphate on tomatoes. Small concentrations stimulate the rate of germination and the general development of seedlings. Germination takes place in the presence of relatively high concentrations, although the resulting seedlings do not show any subsequent development. Where definite poisoning occurs the effects are considerably reduced by the

applications of certain artificial fertilisers, but particularly by slaked lime. Addition of uncontaminated soil round the stems of the plants is beneficial and even when there is little room for such soil as in shallow seed boxes, stunted seedlings make reasonable development. It is noteworthy that the toxicity of copper sulphate is much higher than that of the same concentration of copper in Cheshunt Compound.

A case of plant poisoning has been traced to the presence of chlorates in the soil. Its distribution was uneven and the concentration varied between 0.19 per cent. and 0.05 per cent. With the chlorate was associated an iodate at a concentration innocuous to tomato plants. It was found later that iodates exist in a number of tomato soils.

Previous work has shown that there is some interdependence between soil phosphates and the potash content of tomato foliage, and between soil potash and the phosphoric acid content of the foliage. This was further investigated in 1927 by the examination of foliage in plots receiving increasing amounts respectively of potash and phosphates. The progressive increase of phosphates applied to the soils is accompanied by a corresponding increase in the potash content of the foliage. The progressive increase of potash applied is accompanied by a reduction in the amount of phosphoric acid in the foliage.

DIRECTOR'S REPORT.

1. Experimental Results of 1928.

The practice of grading the tomato fruits from the experimental plots, adopted in 1921, was continued during the present season. The fruits were collected in numbered baskets, and graded in eight grades as follows:—

- A.—“Pinks” number 5 to 7, and “Pink and White” 8 to 10 to the lb. These are the best quality of fruit in size, shape, and colour; “Pinks” being slightly larger than “Pink and Whites.”
- B.—“Whites.” These fruits are of good colour, but smaller than “Pink and Whites.”
- C.—“Blues.” This grade consists of fruit of good colour, but larger and more irregular in shape than Grade A.
- D.—“Roughs.” Small mis-shapen fruits about the size of cherries.
- E.—Blotchy fruits which ripen irregularly.
- F.—Fruit shewing Blossom End Rot.
- G.—Fruits shewing the lesions of Stripe Disease.
- H.—Fruits shewing “Green Back.”

A. Manurial Experiments with Tomatoes.

(a) House 1. Planting Experiment.

In general practice, young tomato plants are planted directly from size 60 pots into holes punched in the soil by means of a mechanical dibber, which consists of a heavy piece of metal resembling in shape and size a ball of soil turned out of the pot. The metal is extended as a flat circular plate at the widest end of the mould to prevent the dibber from being driven too deeply into the soil. A handle, about 2 feet long, is fixed at the plate end. In light soil the dibber serves the double purpose of making the planting hole and tightening the soil. In heavy soils the ramming round the outside of the hole forms a hard layer which may be actually injurious to the plant when the roots commence to push outwards into the surrounding soil. This being so, an experiment was arranged in which four plots in House 1 were planted in holes made by the dibber in the usual way, while four plots were planted so that the soil lay loosely round the young plant. In

the latter case, a hole, sufficiently large to take a size 32 pot was made with a trowel, and when introducing the plant from the 60 pot, washed ashes were packed round the smaller hole to fill up the space which remained. The method cannot be recommended because great difficulty was experienced in keeping the soil round the plant sufficiently moist in the early stages. The crop (table 1) did not shew any difference in favour of either method, and the only conclusion possible is that the mechanical dibber may be freely used on soil similar in type to that existing in House 1. The soil is not heavy and the extreme effect of ramming was not observed.

(b) "Stopping" versus "Non-Stopping."

Four plots in House 1 were stopped in the normal way while four remained unstopped. The results are slightly in favour of non-stopping; the difference in yield was not so great as in the previous year. Observation shews that unstopped plants maintain a better balance between fruit and foliage than those stopped at five trusses, where there is a tendency to very rapid growth after the bottom crop has been picked. To keep this luxuriant growth of foliage in check requires more labour than is available on most nurseries; consequently, it develops out of all control, and when it is thinned later, a mass of growth has to be cut away, which, under better conditions, would have gone towards fruit production.

(c) Watering Experiment.

This line of experiments in House 2 commenced in 1926 and was continued in 1927, when the effect of increasing the quantity of water beyond that usually applied per acre was tested. As might be expected it was found that the normal application of 29,000 gallons per acre per week from April to June, followed by twice that amount between June and September, was sufficient under ordinary conditions. On steamed soil, where greater root action and development was possible this quantity of water could be increased by 50 per cent. with advantage.

In 1928, the experiment was changed to one concerning different methods of watering. Two plots, 4 and 7, were watered through a $1\frac{1}{4}$ inch hose in the usual manner; two plots, 3 and 8, were watered through lines of 2 inch drain tiles laid fifteen inches below the surface, one line of pipes under each row of plants; in two plots, 2 and 5, water was allowed to percolate through the walls of 12 inch earthenware pots sunk in the soil between the plants in the narrow rows, the pots being filled up each morning; while in two plots, 1 and 6, the water was applied to trenches six inches deep in which the plants were set out, a double row to each trench. As the earthenware pots did not empty themselves in 24 hours when the bottom hole was sealed, they were prepared

Table 1.

The Effect of Planting in Ashes.

Variety: E.S. 1.

Plot	Treatment.	Grade of Fruit: Percentage.								TOTAL.		
		A.	B.	C.	D.	E.	F.	G.	H.	Lbs. per Plant.	Tons per Acre.	Average tons per Acre.
1	Normal Planting ...	70.48	22.85	—	5.30	0.39	—	0.98	—	5.08	38.61	32.47
3	"	70.93	22.13	0.50	5.37	—	—	1.07	—	3.92	29.79	
5	"	65.61	28.42	—	5.22	—	—	0.75	—	4.01	30.47	
7	"	68.36	24.03	0.74	4.90	—	—	1.97	—	4.08	31.01	
2	Planted in Ashes ...	65.67	26.75	—	5.97	0.46	—	1.15	—	4.47	32.97	31.87
4	"	72.45	20.92	—	5.60	—	—	1.03	—	3.92	29.78	
6	"	68.18	25.11	—	5.50	—	—	1.21	—	4.18	31.77	
8	"	74.73	19.23	0.44	4.47	0.44	—	0.69	—	4.47	33.96	

Table 2.

"Stopping" versus "Non-Stopping."

Variety: E.S. 1.

Plot.	Treatment.	Grade of Fruit: Percentage.								TOTAL.		
		A.	B.	C.	D.	E.	F.	G.	H.	Lbs. per Plant.	Tons per Acres.	Average tons per Acres.
1	"Unstopped"	70.48	22.85	—	5.30	0.39	—	0.98	—	5.08	38.61	83.46
2	"	65.67	26.75	—	5.97	0.46	—	0.15	—	4.47	32.97	
5	"	65.61	28.42	—	5.22	—	—	0.75	—	4.01	30.47	
6	"	68.18	25.11	—	5.50	—	—	1.21	—	4.18	31.77	
3	"Stopped"	70.93	22.13	0.50	5.87	—	—	1.07	—	3.92	29.79	31.14
4	"	72.45	20.92	—	5.60	—	—	1.03	—	3.92	29.78	
7	"	68.36	24.03	0.74	4.90	—	—	1.97	—	4.08	31.01	
8	"	74.73	19.23	0.44	4.47	0.44	—	0.69	—	4.47	33.96	

for the experiment by placing a cork fitted with a glass capillary tube in each hole. At the outset, the pots worked well, and emptied themselves in 24 hours, but later they became clogged by Algal growth and needed a good deal of cleaning. The underground pipes proved satisfactory as conveyors of water, and it was possible to soak the soil completely to the surface.

The results are in favour of planting in trenches, and this is confirmed by the appearance of the plants through the season, these two plots being the best in the house. There is always difficulty in giving just the right amount of water to the young plants, because the slightest excess induces too rapid growth. The trenches remained moist, continuously, and seemed, by conserving the little water applied each day when damping overhead, to hold sufficient moisture for growth of the young plant. The plants watered from below assumed a sickly appearance about July, and the drainage seemed excessive. Next year only half the number of pipes will be used.

The chemical investigation of 1927 indicated a general increase in nitrate nitrogen from January until the commencement of heavy watering, when the amount of nitrate in the soil dropped suddenly. As this fall might be associated with leeching it was thought then that the experiments on watering described above might throw some light on the problem, more especially when water was gradually applied through the sunken earthenware pots. Nitrate determinations during the course of these experiments showed the sudden decrease in nitrates in all plots, and do not confirm the leeching explanations.

(d) Fertilizer Experiments.

House 3, Series J, as well as House 1, were steam sterilised for the 1928 crop. The results were unsatisfactory for, owing to the low night and high day temperatures which prevailed, the two bottom trusses failed to set all the fruits. The temperature experiments described elsewhere indicate the supreme importance of this factor in glasshouse work, and it is noteworthy that the coolest houses suffered most from the prevailing low night temperatures.

Series J received no fertilisers this year, and the results in Table 4, while confirming previous results, illustrate the general levelling effect of sterilisation among the sections a, b, c and d of various plots.

House 4, Series K, received the same treatment as the previous year except that the addition of fresh grass cuttings to the north half of each plot was changed for wheat straw. The results in Table 5 shew a general improvement in favour of the addition of wheat straw. Only in plot 5a is the yield from the straw plot lower than its control.

Table 3.

Methods of Watering.

Variety: E.S. 1.

Plot.	Treatment.	Grade of Fruit: Percentage.								TOTAL.		
		A.	B.	C.	D.	E.	F.	G.	H.	Lbs. per Plant.	Tons per Acre.	Average tons per Acre.
1	Planted in trenches	78.52	13.93	—	2.98	—	0.45	4.12	—	4.38	33.29	31.5
6	"	78.79	14.07	—	2.56	—	0.24	4.34	—	3.91	29.71	
2	Watered through sunken pots	70.55	17.86	0.31	3.57	1.18	0.59	5.95	—	3.36	25.53	26.60
5	"	75.28	18.69	—	3.04	—	0.25	2.74	—	3.64	27.66	
3	Underground watering	70.04	18.79	—	4.38	0.27	0.82	5.70	—	3.67	27.89	31.71
8	"	72.19	16.61	—	3.97	0.46	2.34	4.43	—	4.28	35.52	
4	Normal watering ...	76.24	17.25	0.27	2.85	0.27	0.27	2.85	—	3.83	29.11	30.11
7	"	76.06	16.15	—	3.41	—	0.97	3.41	—	4.09	31.08	

(e) Variety Trials.

The main feature of these trials was the inclusion of varieties resistant to *Cladosporium fulvum*. These included Stirling Castle, and Up-to-Date, tested for the first time this year. None of these varieties can be classed as a good commercial variety, but they are valuable from a breeding standpoint. In 1927 both Up-to-Date and Stirling Castle were crossed with E.S.1, and the F.1 Generation proved resistant this year. The weight of crop was also pleasing.

Resistance to Mildew is indicated by limited infection and sporulation. Small yellow blotches appear on the foliage, but spore are not produced to any extent. The plants were green towards the end of the season ; susceptible varieties were badly infected. Results are on Table 6.

(f) Investigations concerning the Reduction in Yield of the Tomato Crop by Continuous Cultivation in the same Soil.

These experiments were commenced in 1923, in four new tomato houses, three of which (7, 8 and 9) were manured in the usual way, while No. 10 received no manures at all. An average of 55.8 tons per acre was obtained from House 7 ; 55.2 tons per acre from House 8 ; 51 tons per acre from House 9 and 32.3 tons per acre from House 10. In 1928, the average yield from 7, 8 and 9, taking into consideration only those plots receiving standard treatment was 37.75, 33.14, and 46.63 tons per acre respectively.

The object of these experiments has been to discover some treatment which will either maintain the high initial yield or else increase the yield of any year to the first year standard. So far, the best results have been obtained by digging quantities of freshly cut grass into the soil during December or January. The application of wheat straw in 1926 also gave good results.

This suggests that the decrease in yield during succeeding years is caused by green residues and fibre, the first of which is considered to stimulate bacterial activity in the soil and the second to improve the conditions of aeration.

In 1928 the effect of applying either bean straw or wheat straw in excess of the stable manure and base fertilisers normally given was tested in certain plots. In others, in place of stable manure either bean straw or wheat straw was used. The results in Table 7 suggest that wheat straw can be substituted for stable manure during at least a year. Bean straw proved less useful than wheat straw. No improvement was obtained by adding either bean or wheat straw in excess of the stable manure usually given.

Plot 4b, House 7, which had been manured and remained uncropped since the erection of the house in 1923 was planted in 1928, and a crop of 70.76 tons per acre was obtained. It is interesting to note that 70 tons per acre were obtained in 1925

from plot 5b, also manured and fallow since 1923. It seems safe to assume that soil does not deteriorate when covered by glasshouses as was suspected at first.

Plots 4 and 5 in House 8 were sterilised with formaldehyde during October 1927, and seven days later, tulips (Inglescombe Yellow and Bartigon) were planted. One gallon of 40 per cent. formaldehyde was diluted with 49 gallons of water and watered over 18 square yards of surface previously limed and prepared.

The bulbs were planted 3 inches apart, in rows 6 inches apart. They were allowed to develop slowly through the winter and the crop was marketed during the middle of March. Tomatoes were planted among the tulips without lifting the bulbs, stable manure and base fertilisers being omitted. An average yield of 46 tons per acre of tomatoes was obtained, a substantial increase over that from the other plots in the house. The experiment will be extended in 1929 to determine if the increase was due to treatment with formaldehyde or to the presence of tulip roots in the soil.

The soils of two plots in House 8, and two in House 9 were heated electrically by means of buried resistance wires. These experiments are discussed later in the temperature section.

House 10, previously unmanured in most parts, was used for testing the effect of nitrogen, potash and phosphate respectively applied as a top dressing.

It will be seen from Table 7 that the addition of nitrogen (sulphate of ammonia) phosphates (superphosphate) and potash (sulphate of potash) separately have not increased the yield above that from the unmanured plots. A slight increase was obtained by adding phosphate and wheat straw, but both nitrogen and potash with straw were without effect. It will be seen that the fertilisers in combination produced an increase of 50 per cent. on the untreated soil. Plot 7a, which received grass cuttings only gave, the relatively high yield for the house of 33 tons per acre. Plot 4b, fallow and unmanured since 1923, was cropped for the first time this year, and produced 45 tons per acre, which is above the yield obtained for the rest of the house, during the first year 1923. This confirms the result in House 7, plot 4b, and suggests that the fertility of the soil remained unaffected by building a glasshouse over it.

Lime.

Two new houses, 11 and 12, in which the soil contained only a trace of carbonates, was used to test the effect of adding lime in the first year. House 12 received a dressing of two tons of caustic lime per acre applied in a powder form, while House 11 was without lime. The results are shewn in Table 8, where it will be seen that the unlimed house gave a higher yield than that

Table 4.

Variety: "Manx Marvel."

Plot.	*Treatment During 1927 (unmanured 1928).	GRADE OF FRUIT: PERCENTAGE.										TOTAL.	
		A.	B.	C.	D.	E.	F.	G.	H.	Lbs. per Plant.	Tons per Acre.		
J1a	See Footnote	69.01	23.99	2.61	3.91	0.24	—	0.24	—	3.84	29.18		
J1b	As 1a, but dried blood replaced by top dressing mixture	...	...	...	...	...	...	...	...	...	...		
J1c	As 1a, but two dressings of sulphate of potash omitted	71.53	23.20	0.48	4.79	—	—	—	—	4.18	31.76		
J1d	Top dressing mixture throughout the whole season	62.16	28.03	2.79	5.60	0.25	—	1.17	—	4.28	32.53		
J2a	Unmanured	69.56	20.62	3.97	5.14	—	—	0.71	—	4.27	32.45		
J2b	14 lb. stable manure per sq. yd. in '25, none since	50.29	23.45	2.83	4.50	16.10	—	—	2.83	3.54	26.90		
J2c	28 lb. stable manure per sq. yd.	50.68	21.82	2.34	4.37	15.45	—	0.66	4.68	2.96	22.45		
J3a	Sulphate of potash only	41.90	22.32	2.36	5.73	18.94	—	0.66	8.09	2.98	22.49		
J3b	2½% nitrogen and 10% potash	67.16	18.61	5.23	4.18	4.82	—	—	—	4.78	36.33		
J3c	5% nitrogen and 10% potash	67.85	20.87	3.96	3.96	3.36	—	—	—	4.79	36.40		
J3d	7½% nitrogen and 10% potash	75.51	15.15	3.74	4.56	0.82	—	0.22	—	4.82	36.63		
J4a	5% phosphate and 10% potash	72.35	21.35	2.16	3.75	0.39	—	—	—	5.06	38.45		
J4b	2½% phosphate and 10% potash	65.55	25.12	2.45	4.64	2.24	—	—	—	4.50	34.20		
J4c	5% nitrogen, 5% phosphate and 10% potash	66.18	22.46	3.80	5.91	1.43	—	0.22	—	4.23	32.15		
J4d	5% nitrogen, 5% phosphate and 10% potash	68.38	21.74	4.26	5.19	1.43	—	—	—	4.23	32.15		
J5a	7½% nitrogen, 5% phosphate and 10% potash	73.91	20.42	1.75	3.46	0.23	—	—	0.23	4.20	31.92		
J5b	Complete artificials	69.05	20.48	3.83	3.85	2.85	—	0.47	0.47	4.05	30.78		
J6a	Complete artificials without phosphate	69.14	20.73	3.70	3.70	2.47	—	0.26	—	4.77	36.25		
J6b	8% phosphates	71.06	18.24	3.67	3.73	4.41	—	0.19	—	4.61	35.03		
J6c	16% phosphates	67.67	21.69	3.92	3.92	2.60	—	0.20	—	4.91	37.31		
J6d	24% phosphates	69.06	21.39	2.44	4.29	2.04	—	—	0.18	4.96	37.69		
J7a	Complete artificials without nitrogen	73.00	19.36	2.20	3.63	1.62	—	0.19	—	4.22	32.07		
J7b	5% nitrogen	59.26	18.24	4.01	3.33	13.04	—	2.12	—	3.76	28.57		
J7c	7½% nitrogen	60.37	21.28	3.19	5.32	9.31	—	0.53	—	3.66	27.81		
J7d	10% nitrogen	57.11	21.32	2.44	4.92	12.59	—	1.62	—	4.35	33.06		
J8a	Complete artificials without potash	59.77	20.93	5.29	3.90	9.20	—	0.70	0.21	4.35	33.06		
J8b	7½% potash	36.97	16.30	3.79	3.01	35.85	—	0.54	3.54	3.68	27.97		
J8c	10% potash	38.71	19.04	1.76	3.87	30.68	—	0.89	5.05	3.36	25.53		
J8d	12½% potash	47.33	18.72	5.35	5.10	19.77	—	—	3.73	3.74	28.42		
		53.74	17.17	3.84	8.79	11.73	—	0.89	3.84	4.43	33.66		

BASE.—7 lb. stable manure, ½ lb. sulphate of potash, per sq. yd. Top.—(a) 2 oz. sulphate of potash per sq. yd. with first watering, and 14 days later. (b) Followed by 2 oz. per sq. yd. of a 7½ : 5 : 10 mixture until 7 days before stopping. (c) 7 days before stopping, 1 oz. dried blood per sq. yd., 14 days later 2 oz. dried blood per sq. yd. Afterwards top dressing mixture and dried blood alternately.

* The plots were steamed for 1928 and were unmanured.

Table 5.

Variety: "E.S. 1 $\times$ Comet.—F. 1."

Plot.	Treatment.	GRADE OF FRUIT: PERCENTAGE.								TOTAL.	
		A.	B.	C.	D.	E.	F.	G.	H.	Lbs. per Plant.	Tons per Acre.
K1b	Twice complete artificials (Formula I)	83.11	13.05	—	2.18	1.35	—	0.31	—	3.68	27.97
K1a	Twice complete artificials with straw	83.39	13.78	—	1.40	0.55	—	0.88	—	3.55	26.98
K2b	Unmanured	59.62	11.49	0.84	1.28	23.43	—	1.67	1.67	2.35	17.85
K2a	Straw only	64.00	11.44	1.02	1.33	18.53	—	2.35	1.33	2.97	22.56
K3b	Standard with complete artificials	82.86	14.54	0.27	1.17	0.58	—	0.58	—	3.37	25.60
K3a	Standard with complete artificials with straw	85.92	12.48	0.25	1.10	—	—	0.25	—	3.61	27.42
K4b	Complete artificials with dung	81.34	14.08	0.56	0.88	1.14	—	2.00	—	3.48	26.44
K4a	Complete artificials with dung and straw	79.98	12.66	0.80	1.32	1.04	—	4.20	—	3.79	28.00
K5b	Complete artificials	85.26	10.88	—	0.78	1.54	—	1.54	—	3.86	29.32
K5a	Complete artificials with straw	85.20	10.65	—	1.08	1.08	—	1.99	—	3.66	27.80
K6b	Complete artificials without phosphates	86.16	9.98	—	1.09	0.26	—	2.51	—	3.61	27.43
K6a	Complete artificials without phosphates, with straw	84.40	10.44	—	1.08	3.00	—	1.08	—	3.64	27.65
K7b	Complete artificials without nitrogen	83.26	10.92	0.36	1.94	1.58	—	1.58	0.36	2.57	19.53
K7a	Complete artificials without nitrogen, with straw	81.03	12.21	1.15	1.91	3.06	—	0.32	0.32	2.62	19.90
K8b	Complete artificials without potash	66.91	8.36	1.01	1.67	17.74	0.31	3.34	0.66	2.99	22.72
K8a	Complete artificials without potash, with straw	71.88	8.09	3.18	0.96	13.45	—	1.96	0.48	4.09	31.08

receiving lime, the average yield from four plots in the former being 52·7 tons per acre as against 40·7 tons per acre in the latter.

Stable Manure.

Two plots in each house received stable manure at the rate of 30 tons per acre and two at the rate of 15 tons per acre. As in previous experiments the yield was not appreciably increased by the heavier dressing, the average yields being 47·0 tons and 46·7 tons per acre respectively.

Top Dressing.

All plots in the above houses received the same base fertilisers, namely half a ton bone meal, bone flour and sulphate of potash per acre respectively. Two plots in each house received top dressing at the rate of two ounces per square yard, and two plots half that quantity. The results are slightly in favour of the heavier dressing, which produced an average yield of 48·2 tons per acre as against 45·4 tons per acre.

Table 6.
Variety Trials.

Variety.	Grade of Fruit: Percentage.								TOTAL.	
	A.	B.	C.	D.	E.	F.	G.	H.	Lbs. per Plant.	Tons per Acre.
Up-to-Date × E.S. 1	67·56	16·06	11·77	1·15	1·98	—	0·98	0·50	6·04	45·90
E.S. 1 × Stirling Castle	73·56	14·79	8·55	0·77	0·77	—	0·97	0·59	5·14	39·06
Stirling Castle	58·41	16·24	20·19	2·19	2·37	—	0·60	—	5·05	38·38
Bountiful ...	80·46	15·57	1·73	1·22	0·51	—	0·51	—	4·95	37·54
Paul's Cropper	61·56	9·87	25·21	1·46	0·41	0·22	—	1·27	4·76	36·18
Paul's New Cross ...	62·09	12·28	22·40	1·73	0·65	—	0·85	—	4·64	35·26
Tuckwood ...	66·15	9·87	18·26	0·87	1·41	—	2·70	0·74	4·55	34·55
Ailsa Craig ...	79·33	15·89	2·56	0·88	0·21	—	0·68	0·45	4·50	34·20
Capelle's Beauty ...	45·45	7·81	40·55	0·78	2·96	0·23	0·84	1·38	4·41	33·52
Market Favourite	63·89	18·63	13·55	1·39	1·15	0·24	0·70	0·45	4·35	33·06
Blako ...	64·72	17·02	11·88	1·03	1·73	—	2·38	0·24	4·32	32·80
Satisfaction	30·96	4·94	51·41	2·34	5·41	0·71	4·23	—	4·26	32·38
Blackpool ...	73·97	20·68	4·61	0·74	—	—	—	—	4·11	31·24
Comet ...	36·61	4·28	55·81	1·11	1·39	—	—	1·30	3·65	27·70
Up-to-Date ...	46·77	5·57	33·98	3·63	2·24	—	6·42	1·39	3·59	27·28
Solid Giant ...	20·70	3·00	69·70	1·19	1·50	—	3·91	—	3·33	25·31
Maincrop ...	17·76	3·01	66·90	1·50	1·19	0·91	8·72	—	3·32	25·23

House	5b 6a 6b	Control to 5a Sown with sweet meletot Control to 6a	...	...	...	78.96 78.81 82.76	16.37 14.07 14.87	— 0.31 0.17	1.42 2.01 1.41	— 0.47 0.21	— — —	3.25 4.33 0.48	— — —	7.09 6.37 6.37	53.89 49.18 49.18
House 10	1a	Unmanured	...	...	...	72.46	16.82	—	1.85	6.41	—	1.85	0.61	3.27	24.85
	5b	"	...	...	...	61.25	18.78	0.60	8.17	9.09	—	2.11	—	3.30	25.08
	6a	"	...	...	...	47.54	17.37	0.40	2.23	30.57	—	1.89	—	2.65	20.15
	8b	"	...	...	...	65.97	19.60	—	2.97	9.79	—	1.67	—	2.35	17.86
	2b	Phosphate only	...	...	...	53.73	19.69	—	2.42	17.20	—	6.96	—	2.44	18.54
	2a	" and straw	...	...	...	68.82	18.54	—	1.78	8.24	—	2.62	—	3.40	25.84
	3a	Potash only	...	...	...	67.20	14.81	—	2.24	12.86	—	2.89	—	3.11	23.63
	8a	" and straw	...	...	...	56.82	17.44	0.78	1.56	18.65	—	3.97	—	2.52	19.15
	3b	Nitrogen only	...	...	...	63.33	18.35	—	2.78	12.76	—	2.78	—	2.51	19.07
	4a	" and straw	...	...	...	66.55	19.44	0.36	2.38	8.17	—	3.10	—	2.93	22.27
	6b	Nitrogen, phosphate and potash	...	...	...	69.24	17.04	—	2.54	8.13	—	3.05	—	3.93	29.87
	7b	" , potash and straw	...	...	...	73.96	16.22	—	1.38	4.56	—	3.88	—	4.38	33.29
	5a	" , straw	...	...	...	65.28	18.93	—	1.83	10.53	—	3.43	—	3.80	28.89
	1b	" , grass	...	...	...	70.54	21.15	—	2.44	3.17	—	2.69	—	4.11	31.24
	7a	Grass only	...	...	...	69.28	19.63	—	2.55	4.38	—	4.16	—	4.33	32.91
	4b	Fallow since 1923	...	...	...	58.45	13.23	4.53	2.18	19.10	—	2.51	—	5.97	45.38

B. Cucumber Experiments.

The series of experiments started in 1922 concerning the base or soil upon which the beds are placed, terminated in 1927, with the exception of one experiment in Houses D and E which was continued for another year.

The results in these two houses obtained during 1922-1928 are summarised in Tables 8 and 9.

It will be seen that taking an average of six years results the crop over the steamed base amounted to 107·38 tons per acre, or a little over two flats per foot, while the control plants produced 83·32 tons per acre or about 1·6 flats per foot. This represents approximately an increase of half a flat per foot and amply proves the value of steaming cucumber bases each year.

The results of the 1928 experiments are detailed in Table 10 and the composition of the beds and top dressing treatments in Table 11.

The beneficial effect of steaming the base is seen in plot D2 where the crop is 32 per cent. higher than the control D4. The old bed D3 which has now been steamed over concrete for four successive years is still 12 per cent. above the control, the new big bed E3 is 29 per cent. higher than the control. This fact and the appearance of the plants during the growing season clearly indicates that a bed cannot be steamed indefinitely when it lies over concrete. It does not follow that beds placed over a soil base, and to which new soil is added occasionally will depreciate in the same way as the result of continued steaming. Indeed, it is believed they do not.

The relatively small increase of 14 per cent. over the control shewn in E2 where a layer of turf and ashes was placed between the concrete and the new bed is accounted for by the incidence of *Fusarium* root rot, which presumably came from the turf.

A new set of experiments was commenced in 1928, for the purpose of studying the actual bed in which the plants are grown. In the first instance, there appears to be little reason for the use of so much nitrogenous material in cucumber beds as is given in the form of stable manure, and if a large quantity of manure is necessary its effect may be due to an improved mechanical condition.

In House C an experiment was arranged to determine if a normal crop can be grown in a bed composed mainly of soil reinforced by suitable applications of fertilisers. Two beds, C2 and C4, were normal in every respect, being composed of two parts baked soil and one part stable manure, while two beds, C1 and C3, were made up without stable manure.

Table 8.

House D, 1922-1928.

Year.	PLOT 2.		PLOT 3.		PLOT 4.	
	Soil Base.		Concrete Base.		Concrete Base.	
	Treatment.	Tons per Acre.	Treatment.	Tons per Acre.	Treatment.	Tons per Acre.
1922	Steamed base	101.93	New bed on ashes	73.39	New bed on ashes	73.39
1923	Untreated base	83.77	Bed touching concrete	75.27	Bed touching concrete	75.27
1924	Steamed base	85.76	„	72.61	„	72.62
1925	„	95.46	Bed of 1924	67.11	Old bed steamed	90.51
1926	„	116.06	Old bed steamed	105.97	Old bed removed & steamed	88.09
1927	„	97.53	„	90.94	Old bed steamed	90.94
1928	„	105.52	„	88.24	„	88.24

Average steamed base (D.2) 100.38 tons per acre.

The base of the entire house had been steamed in January, and in the case of C1 and C3 it was covered with a thin layer of washed ashes. Small heaps of baked soil to which a little ashes had been added were placed in position to receive one cucumber plant per heap. The heaps were top dressed with baked soil, to cover the new roots which developed during the season and occasional dressings of dried blood, nitrate of potash and superphosphate were given. Twice during the year, June and August, a little bean straw was applied to keep the bed open.

The results shew a slightly lower yield from the beds receiving no stable manure, but the crop of 1.75 flats per foot is sufficiently good to warrant repetition, and suggests that stable manure is not an absolute necessity for cucumber beds.

Table 9.

House E, 1922-1928.

Year.	PLOT 2.		PLOT 3.		PLOT 4.	
	Concrete Base.		Concrete Base.		Soil Base.	
	Treatment.	Tons per Acre.	Treatment.	Tons per Acre.	Treatment.	Tons per Acre.
1922	New bed touching concrete	79·88	New bed touching concrete	79·88	Control	75·35
1923	New bed on ashes	78·81	New bed on ashes	78·81	„	80·24
1924	New bed touching concrete	76·05	New bed touching concrete	72·06	„	83·43
1925	Bed of 1924	61·08	Old bed steamed	97·70	„	77·30
1926	New bed ...	89·02	New bed ...	89·02	„	96·36
1927	„ ...	85·50	„ ...	85·50	„	91·84
1928	„	107·49	New bed over ashes and turves	90·37	„	78·76

Average control (E.4) 83·32 tons per acre.

Previous experiments have shewn that increased crops can be obtained by mixing clinker with the beds, and it was decided to try the effect of using lump chalk which might be expected to neutralise any acids formed, in addition to keeping the beds open.

One bed, D1, was treated in this way, and the result seemed definitely harmful. The lumps of chalk became very slimy at the surface, and this tended rather to bind the bed than otherwise.

The admixture of bean straw and ashes with cucumber beds was carried out in House F, plots 3 and 4. It gave an increased yield in beds placed over a soil base, but not over a gravel base, and therefore emphasises the importance of good drainage in cucumber beds.

Table 10.

Plot No.	Treatment.	Pounds per Plant.							Total.	Tons per Acre.	Flats per Foot.	Relative.
		March.	April.	May.	June.	July.	Aug.	Sept.				
*C1	Soil only	2.15	14.19	13.10	12.06	10.54	6.84	0.60	59.47	89.20	1.80	113
C3	"	1.26	11.05	13.30	12.26	10.34	7.04	1.32	56.57	84.84	1.71	107
C2	Normal bed	1.34	12.04	14.44	12.96	12.74	9.08	1.61	66.21	99.31	2.00	125
C4	"	2.43	12.15	11.95	13.21	11.04	8.30	0.97	60.25	90.37	1.82	113
D1	Bed made up with chalk	2.41	11.02	9.76	8.12	7.47	6.11	1.03	45.92	68.78	1.39	89
E1	" " ashes	4.23	13.16	13.61	11.07	8.99	8.35	1.40	60.80	91.20	1.84	115
D2	Steamed base, new bed	3.05	15.40	15.91	14.26	12.65	7.36	1.72	70.35	105.52	2.11	132
D4	" " normal bed	3.63	13.89	12.59	8.67	7.31	5.99	1.38	53.46	80.19	1.62	102
E5	" " "	3.59	14.43	13.77	10.80	10.35	6.52	0.93	60.39	90.58	1.82	114
D3	Steamed old bed over concrete	3.11	12.81	12.75	12.02	10.43	6.47	1.24	58.83	88.24	1.78	112
E2	Bed placed on layer of ashes and turfs	4.33	14.33	13.50	11.54	9.25	6.29	1.01	60.25	90.37	1.82	114
E3	New big bed	3.40	15.98	14.51	13.74	10.91	8.45	1.34	68.33	102.49	2.06	129
F2	Gravel bed flooded, normal bed	3.39	17.22	17.25	12.24	9.83	6.85	0.97	67.75	101.63	2.04	128
F3	Gravel base flooded. Bed with ashes and bean straw	2.81	16.23	15.45	13.13	10.26	8.68	1.16	67.72	101.53	2.04	128
F5	Steamed base. Normal bed	3.48	13.40	14.81	14.34	10.71	6.99	0.67	64.40	96.60	1.95	122
F4	Steamed base. Bed with ashes and bean straw	3.51	14.78	16.72	14.31	11.61	7.93	1.38	70.24	105.36	2.11	132
F1	Bed with ashes and hedge clippings	4.35	15.65	14.57	12.61	9.87	7.02	0.55	64.82	97.23	1.96	123
F6	" " "	4.32	14.30	13.34	11.82	10.18	6.30	0.40	60.66	90.99	1.83	115
E4	Control	3.71	11.94	12.40	11.55	8.88	3.72	0.31	52.51	78.76	1.59	100

* House C is a separate house and cannot be compared with D, E, and F.

Table 11.

Shewing the composition of the beds and top-dressing treatment employed in the cucumber experiments.

Plots.	Beds.	Top Dressing.	
		First Dressing : Mar. 13th.	Remaining Dressings : Apl. 14th to Sept. 8th.
C1, C3 ...	Baked soil only	Baked soil. <i>See Note *</i>	Baked soil. <i>See Note *</i> .
D3 	Bed used in 1927, steamed and 50% stable manure added	Baked soil and stable manure with 14 lbs. bone meal to each 100 ft. of border	Baked soil and stable manure with 14 lbs. fertiliser as given in tomato.
All other plots	Two parts baked soil and one part stable manure composted in November	As above	As above

* A special top dressing was applied to House " C " through the season and to the other plots occasionally. It consisted of 2 ozs. per sq. yd. of the following mixture :

1 part sulphate of ammonia
 1 part nitrate of potash
 3 parts superphosphate
 and
 5 parts dried blood.

C. Soil Sterilisation Experiments.

By the kindness of Mr. J. Harnett and Mr. E. S. Shoults it is possible to report upon experiments with formaldehyde carried out during 1928.

At Mr. Shoults' Nursery a block of eight houses, each 180 ft. by 15 ft., cropped first in 1923, was used for the experiment. The crop from these houses had always been unsatisfactory, large numbers of plants dying each year from various root diseases.

The treatments and results are as follows :—

Treatment.					Variety.	Crop Yield in Tons per Acre.
(1) Control	...	...	...	...	Buckley	32.0
(2) „	...	...	...	...	Pale Blako	31.0
(3) Cresylic acid	...	...	...	...	„	40.2
(4) Formaldehyde (40 galls of 2% solution)	...	...	...	...	Ailsa Craig × Blaby	50.2
(5) Grass dug into the soil	...	...	...	...	„	43.0
(6) Formaldehyde (20 galls. 2% solution)	...	...	...	...	„	46.5
(7) Grass	...	...	...	...	„	36.0
(8) Formaldehyde (40 galls. of 0.6% solution)	...	...	...	...	„	39.0

Grass was sown in November, but made little growth until the following February. Growth was checked later by the formaldehyde vapours and it was dug into the soil at the end of the month.

In House 4 a 2% solution of formaldehyde (1 gallon 40% formaldehyde in 49 gallons of water) was applied at the rate of 6.7 gallons per square yard, as it had been found that this quantity of liquid was sufficient to saturate the soil to a depth of 1 foot.

In House 6, half the quantity was applied per square yard, and in House 8 the full quantity of 0.6% solution was applied to the same area.

The solution was applied by means of an injector and the soil was covered with canvas for at least 24 hours. Cresylic acid was used at the rate of 20 gallons 97/99% pale straw coloured material per house, diluted with water to make 2,000 gallons. Treatment took place from December 7th to 14th, and the houses were planted on March 12th.

It will be seen that the same variety was not grown throughout the block, but those employed have been grown for years on this nursery without any appreciable difference in crop being seen between the varieties.

It is obvious that substantial increases in crop yield have resulted from the application of formaldehyde ; the weights of crop increasing with the quantity of formaldehyde applied as below :—

Formaldehyde	...	Full application	...	50.2 tons per acre
"	...	Half application	...	46.5 "
"	...	One-third application	...	39.0 "
Cresylic acid	...	—	...	46.0 "
Controls	...	—	...	31.5 "

The loss in crop in the control houses was due to the number of plants which died by reason of root diseases after the third or fourth truss had been picked. In the grass and cresylic acid houses but few plants died, while in the formaldehyde houses the losses were negligible.

In Mr. Harnett's experiments two houses, each 150 ft. by 26 ft., were treated with formaldehyde, two with cresylic acid, while one remained untreated as a control. Cresylic acid was applied at the rate of 1 gallon to 9 square yards, diluted with water at the rate of about 1 in 129. Formaldehyde was used as a 2% solution at the rate of 50 gallons diluted formaldehyde to 18 square yards, the soil being dug 1 ft. deep immediately after treatment.

The results were as follows :—

Formaldehyde	...	...	...	40.32 tons per acre
Cresylic acid	...	...	...	36.04 "
Control	...	...	...	33.89 "

Here again the crop was increased by treatment with formaldehyde, the relatively low yield throughout being due to the fact that the variety Comet was grown in all the houses.

The use of formaldehyde as a soil sterilising agent has barely passed the preliminary stages, and much investigation is necessary before it will be possible to get the best out of the treatment, but results already obtained are sufficient to encourage growers to try the method on their own nurseries. It cannot compete with steam sterilisation, where any serious trouble exists, but it compares favourably with other chemical treatments.

3. Mycological Investigations.

The following diseases previously unreported have been noted during the year :

Host.			Disease.			Cause.
Asparagus sprengeri	...	...	Seedling rootrot	...	...	<i>Fusarium sp.</i>
Chrysanthemum	...	...	Fasciation of young shoots	...	...	<i>B. tumefaciens.</i>
Cyclamen	...	...	Spots on petals	...	...	Bacterial.
Melon	...	...	Root rot	...	...	Sclerotial fungus.
Narcissus	...	...	Bulb rot	...	...	<i>B. carotovorus.</i>
Rose	...	...	Root rot	...	...	<i>Fusarium sp.</i>
Runner bean	...	...	Crown gall.	...	...	<i>B. tumefaciens.</i>
Solanum capsicastrum	...	...	Chlorosis	...	...	Physiological.
"	...	...	Root rot	...	...	<i>Colletotrichum atramentarium.</i>
Tulip	...	...	Bulb disease	...	...	<i>Penicillium sp.</i>
Viola sp.	...	...	Root rot	...	...	<i>Phytophthora sp.</i>

1. Investigations on the Control of *Verticillium* Wilt of the Tomato.

P. H. WILLIAMS.

During the past two years an attempt has been made to determine if tomato plants suffering from *Verticillium* Wilt disease can be cured by applying chemical compounds to their roots. In 1927 the experiments were conducted in the open as glasshouse accommodation was not available. Under these conditions, which were not the most favourable for the disease, some benefit was obtained by applications of several compounds, the most promising being potassium permanganate, ferrous sulphate, and a mixture of equal parts of lime and magnesium carbonate.

In 1928, it was possible to continue the work under glass, and therefore the above compounds were tested on a fairly large scale. New compounds were also tried.

The method, similar to that used previously, consisted of inoculating six weeks old plants growing in 32 pots and, a fortnight later, applying the various compounds to the roots either in solution or in solid form. The plants were suitably manured to correct any manurial effect which might be produced by the chemical used.

The effect of the treatments was estimated by recording the increase in the percentage of diseased leaves in proportion to the total number on the plant after four weeks. Further, the extent

of browning in the stem and the percentage of plants producing adventitious roots was noted at the end of the experiment. The temperature throughout was favourable to the disease.

The treatment and results are set out in Table 1.

Table 1.

Results of treating Tomato Plants affected with *Verticillium* Wilt Disease with certain compounds.

Compound.	Treatment.		No. of Plants.	Increase in Percentage of Diseased Leaves.	Average Extent of Browning in Stem, Inches.	Percentage of Plants shewing adventitious Roots.
	Am.	No.				
Lime 1 part ...	} $\frac{1}{8}$ oz.	3	20	+17.8	Not	noted.
Magnesium ...						
Carbonate 1 part						
Do. ...	$\frac{1}{4}$ oz.	3	4	+ 6.4		
Do. ...	$\frac{1}{4}$ oz.	2	4	+11.4		
Do. ...	$\frac{1}{4}$ oz.	1	4	+ 8.5		
Do. ...	$\frac{1}{2}$ oz.	3	4	+ 4.2		
Do. ...	$\frac{1}{2}$ oz.	2	4	+ 2.2		
Do. ...	$\frac{1}{2}$ oz.	1	4	+ 6.2		
Lime ...	$\frac{1}{16}$ oz.	3	4	+ 5.0		
Untreated ...	—	—	24	+ 3.9		
Calcium sulphate	$\frac{3}{4}$ oz.	3	4	+22.8	4.5	25
Potassium permanganate	$\frac{1}{8}$ oz.	3	20	+34.3	8.25	65
Do. ...	$\frac{1}{4}$ oz.	3	4	+25.2	6.75	50
Do. ...	$\frac{1}{4}$ oz.	2	4	+31.4	8.5	50
Do. ...	$\frac{1}{4}$ oz.	1	4	+22.3	13.0	75
Do. ...	$\frac{1}{2}$ oz.	3	4	3 dead		
Do. ...	$\frac{1}{2}$ oz.	2	4	3 dead		
Do. ...	$\frac{1}{2}$ oz.	1	4	+24.5	9.75	75
Copper sulphate	$\frac{1}{32}$ oz.	3	4	+29.7	14.25	100
Untreated ...	—	—	48	+28.1	9.5	68
Lithium chloride 1/4000	200 cc	3	4	+ 8.2	14.25	75
Do. 1/8000	200 cc	3	4	+21.7	14.25	75
Do. 1/16000	200 cc	3	4	+ 8.8	15.75	50
Lithium carbonate 1/4000	200 cc	3	4	+ 7.2	16.5	25
Do. 1/8000	200 cc	3	4	— 8.9	25.5	100
Do. 1/16000	200 cc	3	4	+ 8.9	16.5	75
Untreated ...	—	—	24	+ 7.3	18.0	68
Ferrous sulphate	$\frac{1}{8}$ oz.	3	20	+19.8	20.0	80
Do. ...	$\frac{1}{4}$ oz.	3	4	+16.4	18.75	75
Do. ...	$\frac{1}{4}$ oz.	2	4	+20.2	12.0	50*
Do. ...	$\frac{1}{4}$ oz.	1	4	+10.2	10.5	50
Do. ...	$\frac{1}{2}$ oz.	3	4	2 dead		
Do. ...	$\frac{1}{2}$ oz.	2	4	+33.8	15.0	75*
Do. ...	$\frac{1}{2}$ oz.	1	4	2 dead		
Ferric sulphate	$\frac{1}{32}$ oz.	3	4	+11.6	10.5	—
Do. ...	$\frac{1}{16}$ oz.	3	4	+14.3	17.25	50

* 1 dead.

[continued overleaf.]

Table 1 (continued).

Compound.	Treatment.		No. of Plants.	Increase in Percentage of Diseased Leaves.	Average Extent of Browning in Stem, Inches.	Percentage of Plants shewing adventitious Roots.
	Am.	No.				
Untreated ...	—	—	52	+ 9.3	16.0	58
Ferric sulphate ...	$\frac{1}{8}$ oz.	3	4	+19.5	17.25	50
Sodium nitrate 15 pts., mercuric chloride 1 part, 1/125 ...	200 cc	3	4	+ 6.2	11.25	75
Mercuric chloride 1/1000 ...	200 cc	3	4	+23.0	10.0	25
Do. 1/500 ...	200 cc	3	4	+22.5	12.0	50*
Do. 1/250 ...	200 cc	3	4	+20.8	2.25	75
Sodium nitrate ...	$\frac{1}{16}$ oz.	3	4	+20.5	17.25	50
Do. ...	$\frac{1}{8}$ oz.	3	4	+17.5	21.75	75
Potassium nitrate ...	$\frac{1}{16}$ oz.	3	4	+15.0	21.0	100
Magnesium nitrate ...	$\frac{1}{32}$ oz.	3	4	+19.4	13.0	25*
Do. ...	$\frac{1}{16}$ oz.	3	4	2 dead	21.0	—*
Do. ...	$\frac{1}{8}$ oz.	3	4	+18.7	21.0	—*
Untreated ...	—	—	44	+23.9	15.1	36

* 1 dead.

The results shewn above do not confirm those obtained in 1927, but this may be due to the plants having grown in the open that year. Especially is this so in the case of potassium permanganate, which not only proved ineffective but was harmful in the highest concentrations.

The most promising result was that obtained by a mixture of mercuric chloride and sodium nitrate, which will be further tested during 1929. Some benefit resulted from a mixture of lime and magnesium carbonate and also from calcium sulphate. Two compounds of lithium were tried but in view of their poisonous action on the tomato plant they could only be employed at concentrations too low to be of any value.

2. The Effect of some Lithium compound on Tomato Plants.

P. H. WILLIAMS.

During the course of the experiments on the control of *Verticillium* Wilt, plants were treated with lithium chloride and lithium carbonate. At the time of the first treatment a few red spider were observed and accordingly the plants were thoroughly sprayed with oil emulsion. Following this treatment Oedema developed, accompanied in some cases by scorching and distortion of the leaves. Among 26 plants which received no lithium salts, there was no scorch or distortion of the leaves, and only two very slight cases of Oedema.

The association of Oedema with the lithium treatment was very striking and a further experiment was carried out. Plants were treated with amounts of lithium carbonate varying from 1 gm. to 0.2 gm. per pot, the salt being watered into the soil. Four plants were treated at each concentration and two of these were sprayed with oil emulsion, two being left unsprayed. An equal number of plants was kept as controls and half of these were sprayed. The results are shewn in the following table.

Table 2.

The effect of treating Tomato Plants with Lithium Carbonate in conjunction with an Oil Emulsion Spray.

1 gm.	...	Oil	...	Distortion, scorch, oedema.
1 gm.	...	No oil	...	Distortion, scorch, oedema on one plant.
0.8 gm.	...	Oil	...	Distortion, scorch, oedema.
0.8 gm.	...	No oil	...	Distortion, scorch.
0.6 gm.	...	Oil	...	Distortion, scorch, oedema.
0.6 gm.	...	No oil	...	Distortion, scorch.
0.4 gm.	...	Oil	...	Distortion, scorch, oedema.
0.4 gm.	...	No oil	...	Distortion, scorch.
0.2 gm.	...	Oil	...	Oedema only.
0.2 gm.	...	No oil	...	Distortion, scorch, oedema on one plant.
Control	...	Oil	...	14 plants, 3 slight oedema.
Control	...	No oil	...	14 plants, 1 very slight oedema.

It is evident from these results that the lithium compounds favour Oedema when used in conjunction with an oil emulsion spray. The latter may be expected to check transpiration to a certain extent by clogging the tomato while the lithium salts may stimulate water absorption through the roots. No decisive evidence in favour of this hypothesis has, however, been obtained.

The distortion and scorch produced by these substances are of interest in view of the similar effects caused by chlorates which were noted in 1927. In severe cases (1.7 gms. of lithium chloride) only the tip of the plant remained alive after 6 days. The leaves were distorted and yellowish green in colour. With 1 gm. of lithium carbonate, the first symptoms appeared in 8 days. After 23 days the plants were pale green. The edges of the leaves were reflexed, and were lighter in colour on the younger leaves and dead on the older. Dark brown patches appeared on the leaves. The petioles were often twisted so that the lower surface of some of the leaflets was uppermost. On one plant, water-soaked areas appeared on the stem, but no lesions appeared in the interior. The sepals of the flowers were scorched and many of the flowers fell off.

With decreasing amounts of the salt the symptoms became less severe, the younger leaves improving in colour. Plants receiving 0.2 gm. were nearly normal as far as the upper leaves were concerned, scorching being confined to the lower leaves. The leaflets were, however, shorter and rounder than the normal and the serrations less acute.

Other plants received three successive doses of 0.05 gm. per pot at weekly intervals but no adverse effects were observed.

3. A bacterial disease of the Chrysanthemum.

P. H. WILLIAMS.

In the Thirteenth Annual Report, 1927, an account was given of a disease of the Chrysanthemum, entailing the rotting of the flower bud and flower stalk. The cause of the disease was shewn to be a bacterium, which was described. It was suggested that this organism was related to two species of bacteria already described as parasitic on the Tomato. Direct comparisons have now been made with one of these organisms, *Bacterium vesicatorium* Doidge. *Bacterium exitiosum* was not available in pure culture. They are regarded as identical by Gardner and Kendrick and therefore comparisons of the Chrysanthemum organism with *B. vesicatorium* was thought sufficient to establish the identity of the organism.

Cultural Experiments.

The growth of the organisms in various media was compared. The results are set out in tabular form below.

Table 1.

Comparison of Chrysanthemum Organism and *B. vesicatorium* in pure culture.

Medium.	Chrysanthemum Organism.	<i>B. vesicatorium</i> .
Beef extract agar plate	Cream, somewhat irregular, raised, shining, translucent	Lemon yellow, circular, convex, smooth, shining, opaque.
Beef extract agar streak	Cream, raised, smooth, shining, translucent	Lemon yellow to dark yellow, raised, smooth shining translucent to opaque, consistency often butyrous.
Beef extract gelatine plate	Liquefaction rapid, producing a turbid fluid, the colonies becoming dispersed	Liquefaction rapid. The colonies remain small and form a precipitate. Fluid clear.

[continued overleaf.

Table 1 (continued).

Medium.	Chrysanthemum Organism.	<i>B. vesicatorium.</i>
Beef extract, gelatine stab	Liquefaction infundibuliform to stratiform. Liquid turbid with pellicle and heavy yellow precipitate	Liquefaction infundibuliform to stratiform. Liquid clear with slight precipitate. The heavy pale yellow pellicle is readily shaken down and may be mistaken for a precipitate.
Beef extract bouillon	Turbid, slight pellicle and precipitate	Turbid, slight yellow pellicle and precipitate.
Dunham's solution	Growth as in Bouillon. Slight Indol production in four weeks	Growth as in Bouillon. Indol produced in five weeks.
1% Peptone water plus 1% potassium nitrate	Growth as in Bouillon. No reduction of nitrate in four to five weeks	Growth as in Bouillon. No reduction of nitrate in five weeks.
10% peptone water plus 2% glucose	No acid or gas. Litmus bleached. Medium cloudy with slight pellicle	Colour remains unchanged. No gas. Medium clear. Thick yellow pellicle adhering to side of tube.
10% peptone water plus 2% sucrose	Similar	Similar.
10% peptone water plus 2% glycerine	Similar	Similar.
10% peptone water plus 2% lactose	Similar	Similar.
Milk ...	Peptonised without coagulation. Liquid yellow, turbid, pellicle and precipitate	Peptonised without coagulation. Liquid clear with heavy bright yellow pellicle.
Litmus milk	Slight alkalinity at first, later the litmus is bleached. Final stages as in milk	Litmus is not bleached. The liquid is cleared without coagulation and finally shews an acid reaction.
Potato block	Yellow, wet, shining and spreading. Medium discoloured	Dark yellow, raised, shining. Medium discoloured.
Uschinsky's solution	Litmus bleached, liquid turbid with slight pellicle and precipitate	No growth.

These reactions shew clearly that the organisms are distinct.

Inoculation Experiments.

While it early became clear that no relationship existed between the two organisms, it was thought desirable to carry out some parallel inoculations with them.

CHRYSANTHEMUM.

No infection beyond a slight browning around the stab has been obtained, when *B. vesicatorium* has been inoculated into the stem and flower. Inoculations made at the same time with the Chrysanthemum organism produced distinct lesions and the organism was successfully reisolated. No lesions on the leaf have been obtained by spraying with either bacterium.

TOMATO.

(a) Stab Inoculations.

B. vesicatorium readily infects the Tomato when pricked into the stem, causing a considerable rot of the pith. The lesion may extend to a total length of six inches within a month. The lesion was considerably greater than that obtained with the Chrysanthemum organism and the necrotic tissue was darker in colour. No difficulty was experienced in re-isolating the organism from infected plants.

(b) Spray Inoculations.

B. vesicatorium is reported to be capable of infecting the tomato when a suspension of the organism is sprayed on the plant. Experiments on these lines with the Chrysanthemum organism were unsuccessful in 1927, probably owing to the lateness of the season. During the past year further experiments were carried out. Brown patches and spots were observed on the youngest leaves which were distorted. Plants inoculated with *B. vesicatorium* at the same time also shewed lesions on the leaves which were larger and lighter in colour.

Summary.

- (1) The organism previously shewn to cause a disease of the Chrysanthemum flower has been compared with *Bacterium vesicatorium* Doidge.
- (2) The organisms are shewn to be distinct in cultural characters and to differ in their effects on the Chrysanthemum and Tomato.

4. Fungi occurring in Tomato Roots.

P. H. WILLIAMS.

Since the discovery of the root rot and wilt of the Tomato caused by *Colletotrichum atramentarium*, the roots of some or all of the plants grown in the manurial experiments have been examined each year. This examination has revealed that *Colletotrichum* is quite commonly present on the roots of plants which have appeared quite healthy during the season and borne a satisfactory crop. At the same time a number of roots are

diseased without shewing any of the characteristic sclerotia of the *Colletotrichum*. In many cases the cortex of the root has completely rotted so that the outer layers, which have become cutinised are easily drawn off the central vascular cylinder. These symptoms have been described as characteristic of the *Colletotrichum* disease but absence of the sclerotia suggests that other organisms are responsible in many cases. Undoubtedly much of the rot is secondary, the root having been killed by some physical cause such as waterlogging of the soil. Local browning of the cortex is also common. A second condition frequently observed has been named "Corky Scab." The infected portion of the root varies from half an inch or less to more than a foot. In young stages the root remains white but the outer tissues are cracked. Such roots are often observed in plants submitted for examination. At the end of the season the whole of the tissue is converted into cork and when one of the main roots is involved it may be a quarter of an inch in diameter.

Isolations.

Isolations were made from roots shewing both cortical rot and "Corky Scab." Small pieces were sterilised in mercuric chloride for one or two minutes, washed in sterile water and placed on the surface of agar slopes. Isolations from larger roots were made by cutting out pieces of the interior aseptically. The organisms growing out were purified by appropriate methods.

A large number of pure cultures were obtained, many being duplicates. A list of the organisms isolated is given below :—

Fusarium culmorum.

Fusarium spp.

- A. Cream tufted growth on hard potato agar.
- B. White fluffy growth on hard potato agar. No colour in medium.
- C. White fluffy growth on hard potato agar. Blue colour in medium.

Phytophthora sp.

Colletotrichum atramentarium.

Trichoderma Koningi.

A sterile fungus represented by several strains. The mycelium is white to grey and on certain media a hard stroma-like mass of carbonised hyphae is formed. No spores have yet been observed.

Bacteria.

- A. Cream, small rod.
- B. Dark yellow, rod.
- C. Yellow, coccus or small rod.
- D. Cream-yellow, small rod.
- E. White, coccus.
- F. Cream, coccus.
- G. Yellow, large rod.

Inoculations.

Of the organisms noted above the following proved pathogenic when inoculated into the stem of tomato plants.

Fusarium culmorum. Attacked the wood and pith and one culture was also found to cause wilt of the carnation.

Fusarium sp.

- A. Pith attacked.
- B. and C. Very slight lesions produced.

Phytophthora sp. Produced the typical collapse of the tissues, causing the plants to fall over.

Colletotrichum atramentarium.

Trichoderma Koningi. Slight browning of pith.

Sterile fungus. Lesions slight.

Bacteria. A. Considerable rot of the pith.

B. C. and D. Lesions slight.

Root Inoculations.

Plants growing in sterile soil were inoculated with certain of these organisms. Pieces of a culture were inserted in the soil near the stem of the plant or in the case of bacteria a liquid culture was poured on to the soil. Sterile culture media was used in the case of control plants. Some of the plants were examined at the end of two or three months and the remainder after five months. In the controls the smaller fibres were generally brown while the larger remained healthy. Plants inoculated with *Fusarium C*, the sterile fungus and *Bacteria A and B* presented a similar appearance. There was some evidence of infection with *Fusarium culmorum* and *Fusarium B*.

An attempt to secure early stages of the scab disease was made by growing plants in infected soil, prepared by breaking up diseased roots and mixing them with sterile soil. After a period of incubation, plants were potted up in this soil in sterile "32" pots. An equal number of plants were grown in sterile soil as controls. A certain number were placed in a chamber of the

Isolation House and others in a house used for *Verticillium* investigations where the temperature was somewhat higher. The soil of some of the pots was kept wet by standing them in shallow pans of water. At intervals plants were washed free from soil for examination. There was no significant difference in the appearance of the roots as a result of the different treatments. The fibrous roots were in many cases dead, and on many of the larger roots browning and rot of the cortex appeared.

Colletotrichum, *Verticillium*, *Fusarium* and *Thielavia* were among the organisms present. The controls shewed the same symptoms during the latter half of the experiment. Scab did not appear until after the lapse of six months and then only four out of 68 plants were affected. It is possible that if this disease is caused by a parasitic organism, the latter under these conditions was unable to compete with the other organisms present. Further, the fact that control plants produced diseased roots indicates that secondary infection renders soil inoculations whether with pure cultures or diseased material very unsatisfactory.

The alternative lies in direct root inoculation with pure cultures. It has, however, proved difficult to secure healthy roots suitable for inoculation by growing in soil. Water cultures have, up to the present, been unsatisfactory, the plants dying after a few weeks. During the coming season, however, other formulae will be tried and it is hoped to overcome the problems of technique involved.

5. Tomato "Mildew" or Leaf-Mould.

By T. SMALL.

This investigation has been continued. It is believed that the most satisfactory solution of the problem of mildew control is the cultivation of resistant varieties, and efforts are being made to secure such varieties.

Observations indicate that the damage caused by the disease may be considerably reduced by cultural practices. Most growers realise the importance of atmospheric temperature and humidity but information is needed to enable them to combat the disease more successfully. Hence a detailed study has been made of the relation of atmospheric temperature and humidity to mildew.

Inoculation Experiments.

The plants used in these experiments were grown in rich soil in four inch pots; they were inoculated when about nine inches high. The various series of each experiment included no less than seven plants. Inoculations were made by carefully spraying the lower surface of the leaves with a heavy suspension of spores in water. The spores of *Cladosporium fulvum* are difficult to wet, and

are therefore unevenly distributed in suspension. To obviate the effect of this the suspension was well shaken before transferring a portion to the atomiser, and this portion was used to inoculate one plant from each of the various series under investigation. Since sporulation is limited in pure culture the spores were obtained from diseased leaves. The viability of the spores was tested by suitable methods.

During each experiment the plants were examined on alternate days. It is impracticable to include all the records in the Tables, but the data indicate the development of mildew under the experimental conditions.

The following scheme, based upon the degree of sporulation and the area covered by the fungus, was used to denote the severity of mildew.

Degree of Sporulation.

- B1. Faint grey mould present but little or no sporulation.
- B2. Marked grey mould present and definite sporulation.
- B3. Marked grey mould present and more intense sporulation as shewn by the presence of scattered spots of brown mould. This indicates a severe attack.
- B4. Brown mould covering most of the leaflet. A very severe attack.

Area of Leaflet covered by the Fungus.

- C1. Numerous but scattered spots of fungus.
- C2. Fungus spots coalesced and covering half the leaflet. This indicates a severe attack.
- C3. Fungus covering most of the leaflet. A very severe attack.

A few examples will shew how the scheme was applied. Initial stages of attack were usually denoted by B1, C1. Milder attacks were recorded as "disease appearing." "No disease" implied that none was visible to the naked eye. From the B1, C1 stage progress may occur along different lines and was denoted by B2, C1, or B1, C2, etc. The final and most severe stage was represented by B4, C3. Combinations such as B1-2 or C1-2 were used to denote intermediate stages or that leaflets of the same plant were affected differently.

Experiments made under Controlled Conditions—Temperature Relations.

In these experiments small chambers having glass sides and top were used to accommodate the plants and thermo-hygrographs. Each chamber was maintained at an average temperature which differed from that of the other chambers. An almost constant

humidity, which was about 95 per cent. was maintained in all the chambers. The average temperature and humidity was calculated on a two hour basis from continuous records taken by thermohygrographs which were standardised very frequently. The averages are given to the nearest whole figure. The effect of temperature upon the whole course of the disease was determined, after which its effect upon primary infection, the progress of mildew subsequent to infection and sporulation, was tested.

The effect of temperature upon the whole course of the disease.

This was determined by growing the various series of inoculated plants in chambers maintained at average temperatures of 73, 67, 63 and 50°F. respectively. The details and results are given in Table 1, and show that the plants at 73 to 63°F. were severely diseased while those at 50°F. remained apparently healthy. Some of the latter however, on being moved to a temperature of 73°F. developed mildew in three days, whilst the remainder left at 50°F. remained apparently healthy. This result shews that the plants at 50°F. in the above experiment had become infected but, owing to the low temperature, the disease was almost unable to make further progress. Similar results were obtained in another experiment with plants kept at 55°F. It may be noted here that the spores of *C. fulvum* germinate readily in water at 50°F.

Table 1.
The effect of temperature upon mildew.

Date of Inoc.	No. of Plants	Average Temperature, °F.			RESULT.		
		11-18, 5/28.	18-26, 5/28.	11-26, 5/28.	19/5/28.	23/5/28.	26/5/28.
11/5/28	15	74	72	73	Disease appearing	15 plants, B3, C2	3 plants, B3, C2
						—	12 „ B4, C3
„	„	69	67	67	No disease (*) ...	13 „ B2, C1 2 „ B3, C2	4 „ B2, C1 11 „ B3, C2
„	„	64	62	63	„	13 „ B2, C1 2 „ B3, C2	14 „ B3, C2 1 „ B4, C3
„	„	51	49	50	„	No disease ...	No disease.

(*) In all the Tables "No disease" implies not visible to the naked eye.

The effect of temperature upon primary infection.

In these experiments plants were inoculated and the various series were placed in chambers, maintained at average temperatures of 72, 63 and 57°F. respectively for four days only, and were afterwards moved into a well-ventilated glasshouse where further development of the disease occurred. On moving the plants into the glasshouse controls were inoculated and placed beside them. The controls remained almost healthy which indicated that scarcely any infection occurred on the treated plants after they were moved into the glasshouse. The results are given in Table 2.

Table 2.

The effect of temperature upon primary infection.

Date of Inoc.	No. of Plants	Average Temp., °F. during Exposure Period, i.e., 15-19/6/28.	RESULT.		
			23/6/28.	27/6/28.	3/7/28.
15/6/28	12	72	Disease appearing	5 plants, B2, C1 7 " B2, C2	12 plants, B4, C3
"	9	63	No disease ...	9 " B2, C1	9 " B4, C3
"	12	57	" ...	8 " B2, C1 4 " B2, C2	12 " B4, C3

Severe infection occurred at 72°F. to 57°F., the amount of infection being equal over a wide range of temperature if sufficient time were allowed.

It is worth noting that the highest temperature tested (72°F.) was the most favourable for infection and that its influence was evident throughout the experiment although the plants were exposed to it for four days only. This temperature is within the optimum for spore germination (71-77°F.).

It is also important to note that severe infection occurred at 57°F. in four days under humid conditions. Had these conditions obtained throughout the experiment the low temperature would have checked further development of the disease despite the favourable humidity conditions. This is suggested by the results of experiments already given (see page 47) and others given later. (See Table 3.) Thus, moving the infected plants to the higher temperature but lower humidity of the glasshouse caused a rapid development of mildew.

Another significant result in the above experiment, was that the treated plants developed a severe attack of mildew, while the controls remained almost healthy for several days after the conclusion of the experiment. This result suggests that, after infection has occurred, a severe attack of mildew may develop under conditions which almost prevent infection. This suggestion was tested by inoculating three plants, each three feet high, and placing them in a moist chamber for three days to ensure infection. They were afterwards moved to a sunny position outside at which time three control plants were inoculated and placed beside them. Three weeks after inoculation the treated plants had developed large patches of mildew on numerous leaflets, while the controls, four weeks after inoculation, had two faint spots of mildew only. During the experiment the temperature was favourable to mildew and hence the result was largely determined by the humidity factor. The result indicates, therefore, that a lower humidity is

required to control mildew than to prevent it. For this reason the grower should aim at preventing infection rather than at checking the disease after it has appeared in the crop.

The effect of temperature upon mildew subsequent to primary infection.

This was determined by placing the inoculated plants in a moist chamber to ensure infection, and afterwards moving the various series into chambers maintained at average temperatures of 71, 68 and 59°F. respectively. The results are given in Table 3 and shew that mildew developed severely at 71 and 68°F. but was almost absent at 59°F. The favourable influence of the highest temperature was again evident.

Table 3.

The effect of temperature upon mildew subsequent to primary infection.

Date of Inoc.	No. of Plants	Average Temp., °F. subsequent to Infection.			RESULT.		
		1-8, 6/28.	8-11, 6/28.	1-11, 6/28.	7/6/28.	9/6/28.	11/6/28.
30/5/28	15	71	72	71	Disease appearing	9 plants, B2, C1 6 " B2, C2	15 plants, B4, C3
"	"	68	68	68	No disease ...	12 plants, disease appearing	8 " B2, C1 6 " B4, C2
"	"	60	57	59	"	No disease	12 plants, no disease. 3 plants, disease appearing.

The very slow development of mildew at 59°F. in the above experiment together with the fact, established previously, that severe infection occurs in four days at 57°F., shews that the main effect of low temperatures is to check the disease subsequent to infection. Further evidence supporting this conclusion was obtained at the end of the experiment, when six of the apparently healthy plants at 59°F. on being moved to 71°F. developed mildew in three days, while the remainder left at 59°F. still appeared healthy. The result shewed that the disease required a higher temperature for its rapid development.

The above results suggest an explanation of the sudden epidemics with which growers are so familiar. During cool weather it is extremely probable that infection is constantly taking place, but, owing to the low temperature, the disease develops slowly and mainly within the plant. If at this stage warmer conditions intervene, an apparently healthy crop is transformed into a severely diseased one in a few days. In 1927, despite the humid conditions owing to frequent rain, mildew was far less severe in the experimental houses than in the hotter and drier summer of 1928.

The effect of temperature upon sporulation.

As in most fungus diseases, sporulation is an important factor affecting the spread of mildew. Its relation to temperature was determined as follows. Inoculated plants were placed in a moist chamber for three days, to ensure copious infection, and were afterwards grown in a glasshouse until the disease was just visible. At this stage the various series of plants were placed in chambers maintained at average temperatures of 84°, 72°, 70° and 64°F. respectively. The results showed that sporulation was most abundant at 72° and 70°F. At 84° and 64°F. it was plentiful, and the disease made considerable progress, but these temperatures were respectively above and below the optimum for sporulation.

Humidity Relations.

In these experiments small chambers having glass sides and top were used to accommodate the plants and thermo-hygrographs. The latter were standardised very frequently. The atmospheric humidity was controlled by means of sulphuric acid. The degree of control was affected by the transpiration of the plants and by slight temperature variations, but was considered sufficiently accurate for practical purposes. As far as possible, the experiments were made under optimum temperature conditions. After inoculation the plants were allowed to dry before being placed in the chambers. This simulated natural conditions and also standardised the procedure. Continuous temperature and humidity records were taken from which the average was calculated on a two-hour basis. The effect of humidity upon the whole course of the disease, and also upon the various stages of it, was determined.

The effect of humidity upon the whole course of the disease.

In this experiment the various series of inoculated plants were grown in chambers maintained at average humidities of 98, 79 and 65 per cent. respectively. Optimum temperature conditions obtained. The details and results are given in Table 4.

The results show that mildew appeared and developed most quickly at 98 per cent. humidity. This indicates that *C. fulvum*, in common with most fungi, is favoured by humid conditions.

At 79 per cent. humidity there was less disease, but the result shews that the humidity must be below this to prevent infection when optimum temperature conditions obtain. Evidence supporting this conclusion is given later. (See page 51.)

At 65 per cent. humidity scarcely any disease developed. A careful examination of the leaves failed to detect any germinating spores, and when, at the end of the experiment, the

Table 4.

The effect of humidity upon mildew.

Date of Inoc.	No. of Plants	Average Percentage Humidity.				Av. Temp. °F.	RESULT.		
		11-14 5/28.	14-21 5/28.	21-26 5/28.	11-26 5/28.		19/5/28.	21/5/28.	26/5/28.
11/5/28	7	98	98	98	98	71	Disease appearing	7 plants B2, C1	7 plants B4, C3.
"	"	82	78	78	79	"	No disease	Disease appearing	5 plants, B2, C3. 2 plants, B3, C2.
"	"	68	60	69	65	"	"	No disease	4 plants, no disease 2 plants, few spots.

plants were transferred to a moist chamber they remained healthy for several days. It was concluded that the spores had failed to germinate at 65 humidity.

The above results indicate the beneficial effect of a dry atmosphere.

The effect of humidity upon primary infection.

These experiments were made to determine the degree of humidity required to prevent infection. The various series of inoculated plants were placed in chambers, maintained at average humidities of 95, 80 and 71 per cent. respectively for four days only, which allowed ample time for infection to take place, and were afterwards moved into a well-aerated glasshouse where further development of the disease occurred. On moving the plants into the glasshouse controls were inoculated and placed beside them. The controls

Table 5.

The effect of humidity upon primary infection.

Date of Inoc.	No. of Plants	Period of Exposure.	Percentage Humidity during Exposure Period.			Temp. °F. during Exposure Period.			RESULT.	
			Abs., max.	Abs., min.	Av.	Abs., max.	Abs., min.	Av.	After 10 Days.	After 14 Days.
7/8/28	8	4 days	97	93	95	72	66	69	8 plants, B2, C1	8 plants, B4, C3.
"	"	"	86	80	80	"	"	"	3 plants, disease appearing	3 plants, B2, C1-2. 5 plants, B3, C2-3.
"	"	"	80	64	71	"	"	"	2 plants, disease appearing	5 plants, disease appearing. 2 plants, B2, C1-2.

remained almost healthy, which indicated that scarcely any infection occurred on the treated plants after they were moved into the glasshouse. The average humidity and temperature was calculated from records taken during the period of exposure only. The results of one experiment, made under approximately optimum temperature conditions, are given in Table 5.

The results shew that severe infection occurred at 95 and 80 per cent. humidity and that it was slight at 71 per cent. humidity. From these and other results, obtained in further experiments, it is concluded that infection is rare at 70 per cent. humidity under optimum temperature conditions.

It is interesting to note, however, that in the above experiment slight infection occurred on the plants exposed to an average humidity of 71 per cent. This result suggests that the presence of water on the leaves is not essential for spore germination and infection.

It is instructive to compare the results obtained at 95 and 71 per cent. humidity in the above experiment. These humidities were operative for four days only, but they determined the amount of mildew which developed on the plants when these were growing under identical conditions in the glasshouse. This is often the case in commercial nurseries. Various parts of the same nursery may be affected differently with mildew, and records at this time shew that the temperature and humidity conditions are alike throughout the nursery. It is unlikely that the fungus was confined to certain areas. On the contrary it is very probable that different conditions prevailed in the various parts of the nursery at an earlier date, and the effect of this difference is seen later, and at a time when similar conditions obtain throughout the nursery.

It should also be noted that the plants at 95 per cent. humidity in the above experiment were exposed to this humidity for four days only and that the severe development of the disease occurred subsequently in the glass house under conditions which, as the controls shewed, almost prevented infection. This evidence supports the statement, made previously, that a lower humidity is required to control mildew than to prevent it.

The effect of humidity upon mildew subsequent to primary infection.

In this experiment the various series of inoculated plants were placed in a moist chamber for three days to ensure infection, and were afterwards moved into chambers maintained at average humidities of 98, 78 and 57 per cent. respectively. The results are given in Table 6 and show that the development of mildew was appreciably retarded at 78 and 57 per cent. humidity.

Table 6.

The effect of humidity upon mildew subsequent to primary infection.

Date of Inoc.	No. of Plants	Av. Percentage Humidity subsequent to Infection.			Average Temp. °F. subsequent to Infection.	RESULT.	
		2-9, 7/28.	8-12, 7/28.	2-12, 7/28.		10/7/28.	12/7/28.
29/6/28	9	96	98	98	66	6 plants, disease appearing 3 plants, B2, C1	9 plants, B2, C2-3
"	"	78	77	78	"	No disease ...	Disease scarcely visible
"	"	57	56	57	"	"	"

The effect of humidity upon sporulation.

These experiments were made to ascertain the degree of humidity required to check sporulation. The inoculated plants were placed in an infection chamber for three days, to ensure copious infection, and were afterwards grown in the glasshouse. When the disease was just visible the various series were placed in chambers maintained at average humidities of 92, 78 and 58 per cent. respectively. The results are given in Table 7.

Table 7.

The effect of humidity upon sporulation.

Date of Inoc.	No. of Plants	Date Disease Visible.	Percentage Humidity (20-25/8/28).			Av. Temp. °F. 20-25/8/28.	RESULT.	
			Abs., max.	Abs., min.	Av.		23/8/28.	25/8/28.
10/8/28	8	20/8/28	95	90	92	67	3 plants, B2, C1 5 plants, B3, C2	8 plants, B3, C2-3.
"	—	"	85	70	78	"	5 plants, B2, C1 3 plants, B3, C1-2	4 plants, B2, C1-2 4 plants, B3, C2-3
"	—	"	73	52	58	"	8 plants, B1-2, C1	8 plants, B1-2, C1.

The results show that abundant sporulation occurred at 92 and 78 per cent. humidity, and that at 58 per cent. humidity, the disease spots dried out and produced very few spores.

The relation between temperature and humidity and its effect upon mildew.

Since scarcely any mildew develops at 55°F. under very humid conditions, and since this temperature is below the optimum for tomato cultivation, the question arises whether a rise in temperature above 55°F. must be accompanied by a

considerable reduction in humidity in order to check mildew? Similarly, since infection is scarce at 70 per cent. humidity at the optimum temperature (approximately 72°F.), and since it is almost impossible to maintain such a low humidity in commercial glasshouses, will a fall in temperature below 72°F. permit of a rise in humidity above 70 per cent. without causing severe mildew? In view of the practical significance of these questions efforts were made to obtain data concerning them.

For various reasons the experiments were confined to the primary infection stage of the disease and were conducted as described on page 51.

It was found that scarcely any primary infection occurred in three days at 80 per cent. humidity when the temperature was 66°F. The control plants at 98 per cent. humidity were severely infected. The result indicates that primary infection is appreciably retarded at 80 per cent. humidity when the temperature is 66°F. Reference to Table 6 shews that the development of the disease subsequent to primary infection was checked at 78 per cent. humidity when the temperature was 66°F. Thus the evidence suggests strongly that a combination of approximately 80 per cent. humidity and 66°F. would prevent serious attacks of mildew. If applied at a late stage in the disease these conditions would exercise less control. (See Table 7.)

Experiments made under glasshouse conditions.

While information obtained from experiments made under controlled conditions is fundamental, it is not necessarily applicable to the varying conditions which obtain in glasshouses. Daily maximum and minimum temperatures and humidities may affect the disease considerably. A low humidity during the day may counteract the effect of a high humidity during the night, or a low temperature during the night may nullify the favourable influence of humid conditions.

To obtain further information experiments were made under glasshouse conditions, and simultaneously, a study of these conditions was commenced. The results obtained were determined by so many varying and interrelated factors, that general conclusions only are possible.

The development of mildew at different seasons of the year.

Each month twenty plants were inoculated. Ten of these were placed in the glasshouse at once, while ten were exposed to a high humidity for two days to ensure infection, and were afterwards moved into the glasshouse. The results obtained from both series of plants were similar, and only those from the first series will be considered. This similarity was probably due to the favourable humidity conditions of the glasshouse

which caused infection to occur as quickly and as severely in the first series of plants as in the second. Temperature and humidity records were taken continuously and from these the average was calculated on a four-hour basis.

The results are given in Table 8.

Table 8.

Showing the development of mildew at different seasons of the year (1928).

Month of Experiment.	No. of Plants.	Average Temp. °F.	Average Percentage Humidity.	RESULT.	
				After 2 Weeks.	After 3 Weeks.
January ...	10	54	88	No disease ...	No disease.
February ...	"	55	85	"	"
March ...	"	56	84	"	Little disease.
April ...	"	60	77	Little disease	"
May ...	"	66	81	10 plants diseased	10 plants severely diseased.
June ...	"	67	78	"	"
July ...	"	71	75	"	"
August ...	"	65	79	"	"
October ...	"	60	85	Little disease	"
November ...	"	53	85	No disease ...	Little disease

The results show that the seasonal variations in the severity of mildew were related to the temperature and not to the humidity. When the average temperature of the glasshouse was above 65°F., *i.e.* from May to August, the disease was most severe. It is during these months that mildew causes extensive damage to tomato crops. The results suggest that the humidity conditions in the glasshouse were very favourable to mildew. Such conditions probably obtain in most commercial glasshouses. It is worth noting that during the summer of 1928 hot, dry days, alternated with warm, humid nights occurred in the small glasshouse in which these experiments were conducted. The latter were largely responsible for the severe attacks of mildew which developed, and their harmful effect was not counteracted by drastic ventilation during the day.

Annual variations in the severity of mildew also appear to be related to temperature rather than to humidity. Thus, during the unusually cold year of 1927 mildew was far less severe in the experimental houses than during the warm year of 1928, although the latter year was much drier than the former.

The effect of humid night conditions upon mildew.

Very humid conditions obtain in commercial glasshouses during the night. Their effect upon mildew was tested as follows. Plants were inoculated, and from 6 p.m. to 6 a.m. each night the various series were grown in chambers maintained at the same temperature but at different humidities. During the day all the plants were grown in a well-ventilated glasshouse. The results showed that during warm nights (average temperature about

65°F.), humidities exceeding 75 per cent. caused severe attacks of mildew. Under such conditions drastic ventilation during the day had no appreciable retarding effect upon the disease.

Further experiments were made to determine the maximum number of hours during which plants could be exposed to a high humidity each night and remain healthy. The various series of inoculated plants were placed in a moist chamber for 12, 8, 4 or 0 hours respectively each night. When not in the moist chamber the plants were placed where the humidity was low. The results are given in Table 9.

Table 9.
The effect of humid night conditions upon mildew.

Date of Inoc.	No. of Plants	No. of Hours in Moist Chamber each Night.	Temp. °F. of Moist Chamber each Night.			RESULT.		
			Abs., max.	Abs., min.	Av.	15/8/28.	18/8/28.	23/8/28.
7/8/28	12	12	70	60	66	12 plants, B1, C1	6 plants, B3, C3 6 plants, B4, C3	12 plants, B4, C3.
"	"	8	"	"	"	5 plants, disease appearing	12 plants, B2, C1	12 plants, B4, C3.
"	"	4	"	"	"	7 plants, disease appearing	12 plants, B2, C1	4 plants, B3, C2-3 8 plants, B4, C3.
"	"	0 (Controls)	"	"	"	No disease	No disease	Few disease spots appearing

The results show that all the plants developed a severe attack of mildew except the controls, and suggest that mildew will appear if humid conditions persist for four hours each night.

Bearing in mind the results of the two series of experiments given above the figures in Table 10 should be studied carefully. They were calculated from continuous temperature and humidity records taken in commercial glasshouses among the plants, and show that the humidity exceeded 90 per cent. for more than 9 hours each night. Experiments shewed that dry spores of *C. fulvum*, placed on the leaves of plants germinated overnight under these conditions. It may be mentioned here that alternate drying and wetting of the spores of *C. fulvum*, does not appear to affect their germination.

It is concluded that the persistence of humid conditions during the night is largely responsible for the severe attacks of mildew which occur in commercial glasshouses, and that the control of the disease by cultural practices rests mainly upon the

avoidance of these conditions. Since high temperatures favour mildew, humid conditions during the night are most dangerous in summer. This has been shown experimentally. Some growers attempt to reduce the humidity by keeping the temperature high during the night. Unless the humidity is sufficiently lowered by this practice the higher temperature will favour mildew.

The relation of watering to the disease.

OVERHEAD WATERING. This practice is usually discontinued in summer because the resulting high atmospheric humidity and wetting of the foliage are considered favourable to mildew. To ascertain if wetting of the leaves affected mildew, plants were inoculated and allowed to dry, after which they, excluding controls, were gently and thoroughly sprayed with water each morning and, in some cases, each evening. Morning treatment caused the foliage to remain wet for about three hours. The experiments were made in the glasshouse and were repeated at intervals over a period of two years and under various climatic conditions. The results showed that the treatment had no appreciable effect upon mildew, and suggested that the wetting of the foliage owing to overhead watering does not favour mildew. It may be that the results obtained with small plants are not applicable to dense crops growing under commercial glasshouse conditions. On the other hand, it should be remembered that overhead watering is not practised daily, nor is the foliage so completely wetted as in the above experiments.

The high atmospheric humidity resulting from overhead watering will not persist very long if the practice is carried out early on fine days when ample ventilation can be given, and its effect upon mildew will be unimportant compared with that of the humid conditions known to obtain in glasshouses each night. (See Table 10).

Table 10.

Showing the persistence of humid conditions in commercial glasshouses during the night.

Date of Records.	Ventilation.	Average No. of Hours during which the Humidity exceeded 90% each night.	Average Temp. °F. during the Periods when the Humidity exceeded 90%.
15-26 5-28	None 	13	57
7-16 6-28	„ 	11.5	60
24-30 7-28	Top vents open ...	9.8	61
27-30 8-28	Top and box vents open...	11.3	56

SOIL WATERING. Experiments and observations suggested that spore germination was often caused by the high humidity surrounding the leaves of actively transpiring plants. Thus, when dry spores of *C. fulvum* were placed on the leaves of plants and on glass slips suspended from these leaves, they germinated on the leaves but not on the glass slips. It appeared therefore that turgid plants were more likely to become diseased than plants in a drooping condition. This was tested in the following experiments, which were conducted in the glasshouse and were repeated at intervals over a period of two years under various climatic conditions. Large plants in seven inch pots were used, and while one series was maintained in a turgid state by frequent and copious watering, the other series was very sparsely watered, but was not allowed to wilt. The plants were liberally manured to avoid starvation. For convenience the experiments may be divided into two groups. In the first group the turgid and drooping plants were inoculated and placed in a moist chamber for three days, which allowed ample time for infection to occur, and were afterwards moved into the glasshouse. The drooping plants did not become turgid in the moist chamber. In the second group of experiments the plants were placed in the glasshouse immediately after inoculation. Typical results obtained from several experiments are given in Table 11.

Table 11.
The effect of soil watering upon mildew.

Group.	Treatment.	Total No. of Plants.	RESULT.	
			Turgid Plants.	Drooping Plants.
1	Placed in moist chamber for three days after inoculation and afterwards grown in glasshouse	30	15 plants, B4, C3	9 plants, B2, C1 6 " B3, C2-3
"	" "	12	6 " B4, C3	6 " B2-3, C1
2	Placed in glasshouse immediately after inoculation	30	15 " B4, C3	5 " no disease 10 " B1-2, C1
"	" "	12	5 " B2, C1 1 " B3, C2	6 " no disease.
"	" "	12	6 " B4, C3	"

The results shew that in all experiments the turgid plants became far more diseased than the drooping ones. Humid conditions favour the fungus and also produce turgid plants which are more prone to mildew.

The results from the second group of experiments, *i.e.* where the plants were placed in the glasshouse immediately after inoculation, are of special interest because copious infection occurred on the turgid plants, whereas little infection occurred on the drooping plants. A careful examination of the latter failed to

reveal any germinating spores. The results suggest that the higher humidity surrounding the leaves of the turgid plants was responsible for spore germination, and that its decrease, by means of air currents, would assist in the control of mildew.

Variety Trials.

The object of these trials is to secure a commercial variety resistant to mildew. A susceptible, commercial variety, E.S.1, was crossed with the resistant, but poor cropping varieties, Sterling Castle and Up-to-date. The first generations proved resistant and, as shewn in Table 12, the quality and quantity of the fruit was equal to commercial standards. The second generations will be grown next year.

Table 12.

	Resistant Variety.		First Generations.	
	Up-to-Date.	Sterling Castle.	Up-to-Date × E.S.1.	Sterling Castle × E.S.1.
Total crop in tons per acre...	27.28	38.38	45.90	39.06
Percentage of best quality fruit	46.77	58.41	67.56	73.56

Other resistant varieties tested were Maincrop, Satisfaction and Frogmore Selected. The latter was dispensed with owing to Mosaic disease. Maincrop and Satisfaction shewed marked resistance to mildew, but produced low grade fruit, and hence breeding experiments have been commenced.

Overwintering.

The annual recurrence of mildew opens up the question of how *C. fulvum* overwinters. So far as is known the fungus has no resistant stages and so experiments were made to test if the spores can overwinter.

Diseased leaves buried in soil or suspended from hooks were kept outside from October 1927 to March 1928. In the spring, plants inoculated with a suspension of spores from these leaves developed mildew, while the controls remained healthy. The result suggests that diseased tissue from the previous season is a possible source of the spring infection.

Spores kept through the winter on glass or wood failed to produce infection in the spring. This experiment is being repeated.

The effect of cresylic acid emulsion upon the spores of *C. fulvum* was tested by spraying dry spores on glass slides. When dry, the spores were transferred to water and placed at 77°F. The results shewed that a one per cent. dilution of the acid killed all the spores. In a further experiment the effect of cresylic

acid vapour was tested. A four per cent. dilution of the acid in a watchglass was placed in a petri dish containing a diseased leaf. At intervals spores were transferred from the leaf to water, and placed at 77°F. Exposure to cresylic acid vapour for 23 hours killed the spores.

The results suggest that the possibility of spores overwintering on the glass and woodwork of houses is slight if the houses are thoroughly sprayed with cresylic acid.

Suggestions for controlling Mildew.

At the present stage of the investigation the following may be suggested as a basis for the control of mildew by means of cultural practices.

1. **TEMPERATURE.**—The experiments described previously have shewn that the optimum temperature for mildew is about 72°F. The control of mildew by means of temperatures above 72°F. is scarcely practicable because the temperatures required are so high that they are dangerous to the crop and are difficult to maintain. It is suggested therefore that the temperature should be maintained as much below 72°F. as is practicable. In addition to this precaution it is necessary to avoid humid conditions because under these conditions the beneficial effect of temperatures below 72°F. is not appreciable until temperatures about 60°F. are reached.
2. **HUMIDITY.**—The control of mildew by means of cultural practices rests mainly upon the avoidance of humid atmospheric conditions. When the average temperature is about 65°F. the humidity should not exceed 80 per cent. When the average temperature is about 72°F. the humidity should not exceed 70 per cent.
3. **VENTILATION.**—The adequate ventilation of glasshouses reduces the atmospheric temperature and humidity and causes air movement, and is therefore of great assistance in the control of mildew. Ventilation is necessary during spring to prevent the disease from becoming firmly established. During this season it is very probable that primary infection is constantly taking place but, owing to the low temperature, the disease develops slowly and mainly within the plant. Consequently the crop appears healthy. As early as the season permits drastic ventilation should be given continuously. Some growers do this at the end of April. In summer doors and box ventilators should be opened as well as the top ventilators.
4. **WATERING.**—Whenever possible watering should be carried out early on fine days, and the houses should be ventilated afterwards. In dull weather watering should be either

suspended or reduced to a minimum. Excessive watering produces soft, turgid plants, which are very susceptible to mildew. The practice of overhead watering needs special mention. This practice is carried out frequently in the spring, *i.e.*, during a period when it is difficult to ventilate freely, and is usually discontinued during the summer, *i.e.*, when it is possible to give abundant ventilation. The reverse would probably give better results from the standpoint of mildew control. If, however, growers deem the practice necessary in the spring, it should be carried out early on fine days only when full ventilation can be given.

5. AIR MOVEMENT.—Air movement is beneficial because it reduces the humidity in the immediate neighbourhood of the leaves. It is assisted by opening the box ventilators and doors and by pruning of the lower foliage. Close planting should be avoided.

Summary.

(1.) The severity of tomato mildew is closely related to the atmospheric temperature and humidity. The effect of environmental conditions does not end with primary infection, but the amount of mildew which develops is largely determined by the conditions operating during the early stages of the disease.

(2.) The optimum temperature for the various stages of mildew is about 72°F. Under humid conditions severe primary infection occurs at 50 to 55°F., but the subsequent development of the disease is very slow below 60°F. The temperatures usually prevailing in tomato glasshouses are favourable to mildew.

(3.) Humid conditions favour the fungus and also produce soft, turgid plants which are very susceptible to mildew. The control of mildew by means of cultural practices rests largely upon the avoidance of humid conditions.

(4.) The danger limit of humidity varies with the temperature. Under optimum temperature conditions primary infection is severe at 80 per cent. humidity but is rare at 70 per cent. humidity. Primary infection and the subsequent development of the disease are considerably retarded at 80 per cent. humidity when the temperature is about 66°F. A lower humidity is required to control mildew than to prevent it.

(5.) In summer the persistence of humid conditions for 4 hours each night is liable to cause severe attacks of mildew. Drastic ventilation during the day does not remedy the harmful effect of humid conditions during the night.

(6.) The humidity in commercial glasshouses is rarely low enough to check mildew. The seasonal and annual variations in the severity of the disease are related to the temperature.

(7.) The wetting of the foliage caused by overhead watering does not favour mildew. It is very probable that a film of water on the foliage is not essential for spore germination and infection.

(8.) The hybrids of crosses between a susceptible, good cropping variety, and two resistant but poor cropping varieties, possessed the qualities of resistance and good cropping powers.

(9.) The spores of *C. fulvum* can over-winter on diseased plant tissue. A one per cent. dilution of cresylic acid emulsion is toxic to the spores.

(10.) A basis for the control of mildew by means of cultural practices is suggested.

6. Wilt Disease of the Carnation.

H. L. WHITE.

1. The Disease.

During recent years the damage caused by wilt disease has occasioned much alarm among carnation growers, and it is no exaggeration to say that it has reached such importance that the continuance of carnation growing is threatened in certain districts.

Considerable confusion exists in the minds of nurserymen and others concerning the nature of the disease and it is commonly assumed that there are several diseases of different origin, some of which attack the root and others the aerial parts of the plant. These so-called separate diseases are all related by a common feature—wilt—and investigation has shewn that they are all due to the invasion of the plant by parasitic fungi.

The examination of many hundreds of plants on commercial nurseries reveals that the plants do not shew injury in the same position in all cases. Variation in the position of infected areas causes variation in the type of symptom following infection and gives rise to the supposition amongst growers that there are several different diseases. The positions of the infected areas and types of symptoms to which they give rise can be conveniently explained by the following classification. (See Text—Fig. 1.)

A. Root Disease.

This is the most serious form because the soil becomes infected over a considerable area and the plants wilt in large patches, often at the height of the spring or summer crop. In this case the roots are first infected and shew brown lesions which often extend into the aerial part of the stem before the plants wilt.*

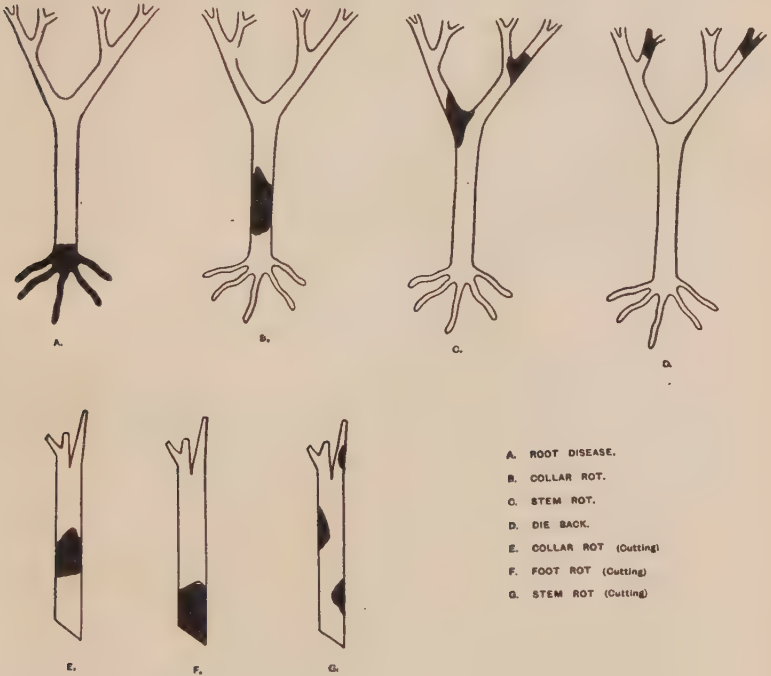


Fig 1.

B. Collar Rot.

Wilted plants shew a brown rot at soil level between healthy stem and roots. Infection takes place at soil level.

C. Stem Rot.

Characterised by a gradual development of wilt which affects the plant limb by limb. Months may elapse before the plant is finally killed. The wood is infected at the junction of the main limbs with the stem of the plant.

D. Dieback.

Infection of small shoots or snags left in cutting blooms is followed by the wilting of any breaks above the point of infection.

* It has been observed that comparatively sudden Wilting of the whole plant follows root or collar infections. In cases of infection above ground the plant dies slowly limb by limb and the disease appears to make no progress for considerable periods.

The fungus grows back discolouring the surface of the infected shoot which becomes white and rough. It rarely grows back into the main stem and under normal conditions has never been observed to cause the death of a plant.

The Wilt Disease in the Propagating House.

The commonest forms of the disease in the propagating house are foot rot, where infection has occurred through the exposed surface made in taking the cutting; collar rot, where infection may usually be traced to a leaf base below the level of the sand or compost; and stem rot, where infection may be traced to a leaf base above the level of the sand or compost. While isolations from wilted cuttings in commercial propagating houses have in some cases yielded the fungus responsible for the wilt disease, in others no organisms have been found and it is clear that much of the wilt in commercial propagation commonly attributed to disease is of physiological origin and due to conditions unsuitable for rooting.

2. Causal Organism.

Isolation of the Causal Organism.

Cultures of *Fusaria* were readily obtained by removing small pieces of browned tissue under aseptic conditions and placing them on slopes of nutrient agar.

The different species obtained were :—

<i>Fusarium</i>	<i>culmorum</i>
„	<i>anthophilum</i>
„	<i>acuminatum</i>
„	<i>herbarum</i>
„	<i>sporotrichoides</i>

Of these, the first four are associated with disease of cereals and grassland, and *F. sporotrichoides* with carnation bud rot. The latter species readily reproduced bud rot but only a slow wilt of the stem.

Inoculation Experiments.

(a) The results of inoculations made on one year old plants in pots, by pricking the fungus into the base of the main limbs are summarised in Table 1.

It may be noted that *Fusarium culmorum* pathogenic to carnations has been isolated from :—

- (1) Asters in a private garden previously grassland.
- (2) Chrysanthemums (outdoor) in a field adjacent to a nursery.
- (3) Tomato roots in a block of tomato houses at the Experimental Station,

Table 1.

Date of Inoculation.	Inoculum.	Origin of Strain.	Number of Inoculation.	Number of Wilted Plants.	Average number of days from Inoculation to Wilt.	Re-Isolations that gave Fusarium Pure or nearly so.	Total Re-Isolations made.	Species of Inoculum on Inoculated Stems.
31/7/26	<i>Fusarium culmorum</i> , lesion at junction of main limbs		3	3	10	2	3	3
"	" " browned wood of wilted cutting		3	3	18	3	3	3
"	" " spores on shoot dying back		3	3	21	1	2	3
"	" " water supply of carnation nursery		3	3	13	0	3	3
"	" " lesion arising from root infection		3	3	19	1	3	2
"	" anthophilum, lesion at junction of main limbs		3	2	24	0	2	1
1/8/26	" <i>culmorum</i> , spores from saprophytic growth on fallen bud ...		3	2	19	2	2	3
"	" <i>acuminatum</i> , lesion at leaf-base ...		3	3	19	3	3	2
"	" anthophyllum, lesion at soil-level traceable to a wound ...		3	3	19	3	3	3
"	" herbarum, spores from superficial lesion on stem of otherwise healthy plant ...		3	1	37	1	1	1
"	Controls		4	—	—	—	2	—
2/8/27	<i>Fusarium culmorum</i> , lesion at soil level ...		3	3	14	0	3	—
"	" " decaying matter on path of carnation house ...		3	3	22	3	6	—
"	" anthophilum, pith lesion ...		6	6	17	3	3	—
"	" herbarum, ...		3	3	—	—	—	—
"	" sp. root lesions		3	No Wilt by 1.2.28	—	—	—	—
"	" sp. root lesions		3					
"	Controls		4	—	—	—	—	—
27/4/28	<i>Fusarium acuminatum</i> , lesions of plants with root disease ...		9	9	8	9	9	—
"	" <i>culmorum</i> aster		6	6	5	6	6	—
"	" " chrysanthemum ...		6	6	6	4	4	—
"	" " tomato root ...		6	6	5	6	6	—
"	" <i>aportrichoides</i> , carnation bud rot ...		6	2	abt. 86	—	—	—
"	Controls		4	—	—	—	—	—

In each of these cases, no carnations had been grown at any time previously on the land.

(b) Inoculations by placing spore suspensions of *F. culmorum* in sterile water on the cut ends of stems resulted in the typical symptoms of "dieback."

(c) The root disease type of symptom has not been reproduced under normal conditions but by partially waterlogging the soil, in a small proportion of the plants inoculated.

Cross Inoculations.

Cross inoculations made on the tomato, aster, and potato shew that strains of *F. culmorum* pathogenic to carnations can cause wilt of the aster and potato and lesions in the stem of the tomato.

Pathological Anatomy.

The causal fungus is capable of producing a pith rot or of travelling in the wood for considerable distances without infecting the pith. The cross plates of tissue at the nodes have the effect of checking the progress of the fungus. On splitting the stem of the diseased plant healthy pith areas may be found alternating with browned infected pith areas, which are connected by browned woods. *Fusarium* has been isolated in many cases free from other organism. from both pith and wood lesions. Where the pith only is infected, the nodal cross-plates may act as barriers for a considerable time, and examinations of plants attacked by "dieback" suggests that the growth of the fungus back into the main stem is often stopped in this way.

3. Observations on a Commercial Nursery.

(1) Incidence of Disease.

The following observations have been made on the incidence of the disease on commercial nurseries.

(a) Dieback.

(1) The growth of the fungus from an infected snag back into the main stem is in the majority of cases stopped at the joint at the base of the snag.

(2) Where the fungus succeeds in passing the joint and working back into the stem the extension of the lesion is so slow that many months elapse before the wilt of shoots on the stem above this point.

(3) Out of many plants examined, none were found with the possible exception of very old plants whose death could be attributed to "dieback." It is considered that the damage caused by the "dieback" type of the disease is not of sufficient importance to warrant consideration of control measures.

(b) Stem Rot.

(1) Twenty-two plants shewing symptoms of "stem rot" were marked in November, 1925, and periodical observations made on them. Only twelve plants had shewn further wilt by the end of August, 1926, and in no case had the wilt become complete and caused the death of the plant.

(2) Of thirteen cases of "stem rot" taken under observation in April, 1926, eight shewed no further wilt by the 26th August. Of the remaining five, three died by the 28th July, and two shewed further wilted limbs.

(3) Observations in detail on a single plant with typical "stem rot" indicated the time taken from infection to complete wilt not to be less than 18 months.

(c) Root Diseases.

(1) It is not unusual for beds destined later to shew large infected areas to have little or no wilt in the first year after planting. Wilt occurs most frequently at the height of the spring or summer crop in the second year. If badly affected beds are allowed to remain the old infected areas gradually enlarge while new ones also appear.

(2) If bare areas are replanted, the new plants wilt comparatively quickly but it must be remembered that reserve plants used for this purpose are often weakened by neglect. The progress of the disease on two infected areas that were replanted on 20/9/25 is shewn in Table 2.

(2) Sources of Infection on Commercial Nurseries.

(a) Atmosphere.

Under favourable conditions sporodochia (spore masses) appear on the surface of diseased plants. They occur most frequently on the stem just above soil level but have also been found upon roots, infected snags on dead leaf-bases and on calyces and petals. It is not uncommon to find plants bearing sporodochia that have not yet begun to wilt. Fresh sporodochia have been found in every month of the year following periods of dull damp weather, but they are most abundant in the winter months—November, December, January and February. In long damp periods in the winter, rotting buds, if infected with *Fusarium*, produce masses of pink sporodochia which are a prolific source of infection.

(b) Water Supply Contamination.

The water supply of a commercial nursery was filtered according to the method devised by Bewley and Buddin. Two *Fusaria* were obtained, similar morphologically to those isolated from living plants. On inoculation, one of these, *F. culmorum*, proved to be pathogenic and shewed that the disease may be spread by contamination of the water supply. Investigations of the sources of the water supplies on other nurseries points to the disease being spread in this way.

(c) Contamination of the Soil.

Various species of *Fusarium* are known to carry on a saprophytic existence in the soil. In the present investigation *Fusaria* afterwards proved to be pathogenic, have been isolated from organic matter on the surface of the paths and from decaying materials in the beds.

The commonest position for sporodochia formation is on the stem just above soil level. Watering or spraying these sporodochia is unavoidable in the ordinary routine work of the nursery and undoubtedly helps the dissemination of the fungus in the soil.

Table 2.

Progress of Disease on Re-planted Infected Areas.

AREA B. AVIATOR.				AREA D. LADDIE.			
Date.	Healthy Plants.	Number of Plants Partially Wilted.	Number of Plants Wilted.	Date.	Healthy Plants.	Number of Plants Partially Wilted.	Number of Plants Wilted.
20/9/25	...	31 (3)*	—	20/9/25	...	8	—
5/1/26	...	21 (3)	—	5/1/26	...	8	—
19/2/26	...	16 (3)	4	19/2/26	...	8	—
23/3/26	...	11 (3)	8	23/3/26	...	7	1
9/4/26	...	8 (2)	2 (1)	8/4/26	...	6	—
29/4/26	...	3 (2)	3 (1)	30/4/26	...	5	1
15/6/26	...	2 (2)	2 (1)	15/6/26	...	5	—
11/9/26	...	— (1)	1 (1)	11/9/26	...	2	—
							6

*The numbers in brackets refer to original plants left in when the area as a whole was re-planted.

(d) Occurrence of the Fungus in Virgin Soil.

The isolation of *F. culmorum*, pathogenic to carnations from Asters, Chrysanthemums and Tomatoes (see Table 1) all growing in situations that had not at any time previously contained carnations, lends strong probability to the assumption that the fungus is present in virgin soil.

(3) Modes of Infection on Commercial Nurseries.

The examination of many infected plants and the positions of their lesions indicates that the wound or injury almost invariably precedes infection by *Fusarium*. The most common points of entrance of the fungus into the plant and the ways in which injuries arise at these points at commercial nurseries are the following :—

During Propagation.

(1) On the surface exposed by making a cutting. The imperfect formation of callus and the breaking away of the callus from the base of the cutting during transference from sand to compost increase the risk of infection.

(2) At soil level both in the cutting stage and when in small pots, especially following deep potting or unsuitable conditions in the sand or compost.

(3) A damaged root. In potting, such roots easily arise by ramming rooted cuttings into infected soil. Excessive ramming increases the risk of infection by interference with the drainage.

(4) At a joint a few inches above soil level. The leaf bases collect moisture which induces decay and aids the germination of fungal spores.

(5) At the cut surface of the snag made in stopping. Such infection is very common but rarely passes the joint at the base of the snag.

After Planting in the Beds.

(6) At soil level. Bites from woodlice or wireworm, and damage from accidental bending or strain from staking long overdue all contribute to the risk of infection. Deep planting and excessive soil moisture lead to "collar rot" apparently by causing splitting, swelling and softening of the tissues, and the exposure of the damaged stem to soil infection.

(7) The root following wireworm bites and other damage. In cases where wireworm attacks have not proved fatal infection by *Fusarium* has been found to follow, and a large percentage of young wilted plants, in which the source of infection may be traced to the soil, have roots or stem bases burrowed by wireworm, gnawed by woodlice or damaged in some way by soil insects.

(8) At the cut surface of the snag made by the cutting of a bloom. It is impossible to avoid leaving a snag but little or no serious damage follows infections of this nature. Similar infections follow accidental breaking of shoots.

(9) The method of infection which leads to "stem rot" (see text—Fig. 1) at the juncture of the main limbs has not been definitely determined. Either the fungus gained entrance through the snag left in stopping, and the disease made such slow progress that the effects were not evident until later in the life of the plant, or it gained entry through the aid of stagnant moisture collected in the main forks of the plant. On two nurseries with contaminated water supply plants with this type of infection were common.

(10) At a joint on a stem high on the plant. Probably resulted through wounds made by dis-budding.

Fusarium may commonly enter the same plant in several different ways. Plants may have been found in which the fungus is both growing up from the root and down from the top.

(4) Effect of Environment on Incidence of Disease.

Temperature.

(1) The period of Maximum Wilt on commercial nurseries occurs during the months of highest temperature, namely from April to August.

The average day temperatures in degrees F. during these months on a commercial nursery were found to be :—

		7 a.m.	1 p.m.	5 p.m.
April	...	57° F	68° F	62° F
May	...	57° F	71° F	69° F
June	...	57° F	73° F	70° F
July	...	60° F	75° F	74° F
August	...	58° F	75° F	75° F

The optimum temperature for the growth of nearly all *Fusaria* lies above 67° F.

It may be noticed that the optimum temperature for the carnation plant lies below 65° F.

(2) Plants inoculated by pricking *F. culmorum*. into the base of the main limbs on 7/9/27 were placed in positions subject to a range of temperatures.

The results are shown on Table 3.

Table 3.

Situation.	Max. Day.	Av. Day.	Min. Night.	Number of Inoculated Plants.	Number of Wilted Plants.	Average Number of Days before Wilting.
Cucumber House	75.5	67.73	57	12	10	19
Cool chamber ...	72	63.5	51.5	12	8	31
Open (sheltered)	59	55.5	48	12	3	—

In another experiment of this nature where the fungus was inoculated into harder stems no wilt occurred, but on examination of the plants after a period of five months it was found that the lesions of the plants in a series subjected to a high temperature were considerably more extensive (average of 6 plants 7.3 cms) than the lesions of plants in a series subjected to a lower temperature (average of 6 plants 3.5 cms.).

(3) Twelve plants were inoculated by placing spore suspensions of the pathogen on the cut ends of the stems. 6 were placed in a cucumber house and 6 in a cool glasshouse.

CUCUMBER HOUSE : In 2 months from the date of inoculation (13/5/27) the fungus had grown back almost to soil level and the plants were killed.

COOL GLASSHOUSE : After 6 months from the date of inoculation (28/4/27) "dieback" had only affected 2 or 3 upper joints. Subsequently the fungus died out without causing further damage.

SOIL MOISTURE : (1) Inoculations by watering the soil with spore suspensions and introducing cultures of the pathogen on steamed carnation stems have given negative results under normal conditions. Wilt has been obtained in a small proportion of cases by partially waterlogging the soil. The inconclusive results of an experiment in which plants were grown for a long period in sterilised soil, thoroughly infected with the pathogen and kept partially waterlogged suggests the operation of another factor.

(2) A bed on a commercial nursery planted in June, 1925, had lost only about 8 per cent. of its plants by June, 1926. By the end of August 60 per cent. of the plants were affected by the wilt disease and the survivors were shortly afterwards pulled out by the grower. The plants showed typical root lesions extending up into the stem and a virulent strain of *Fusarium culmorum* isolated. In the preceding winter this bed had attracted the attention of the writer by reason of its damp condition and poor drainage.

(3) In a house of 1 year old plants which was practically free from wilt disease, a patch involving about 30 infected plants appeared in a side bed in the spring of 1926. This patch was found to correspond with a place on the path outside which was above the level of the bed inside, where the water had collected during heavy rainfall in the preceding winter. In a similar case on another nursery the only infected area on a side bed was found to be also the area of flooding caused by a defect in the drainage system.

Atmospheric Humidity.

Conditions of high atmospheric humidity have always been observed on commercial nurseries or under experimental conditions to produce growth of aerial mycelium and abundant sporodochia, thus increasing the source of infection.

(5) Varietal and Constitutional Susceptibility.

None of the varieties commonly used for commercial purposes have been found to be either immune or resistant. With the doubtful exception of Aviator, no variety has proved consistently susceptible. The variation in susceptibility exhibited by the same variety on different nurseries is sufficiently marked to require consideration.

In past years cases have been reported on the continent of outbreaks of wilt disease following the importation of stock from other nurseries. The cause of such an outbreak might be either the constitutional susceptibility of the stock or the introduction in it of a virulent strain of the fungus.

The variation in constitutional resistance of stocks propagated on different nurseries may well be an explanation of the fact that the same variety contracts the disease badly on one nursery and remains practically free on another where perhaps the general infection is more severe.

The widespread sources of infection—by spores carried through the atmosphere, by contamination of the water supply, soil contamination or in young stock brought on to the nursery—indicate the importance of preserving the quality and inherent resistance to disease of Carnation stocks. Few of the varieties in demand for their commercial qualities last many years; the weakening of the strains by intensive culture renders them unprofitable and other commercial varieties arise to take their place. Moreover, the practice of continuous vegetative propagation by cuttings eliminates the re-combination of genetical characters through sexual propagation, which to some extent may possibly be regarded as a safeguard against degeneration. The development of modern intensive methods of culture in

order to keep pace with the growing demands of the Carnation industry has in all probably lowered the disease-resisting powers of Carnation stocks and been one of the main causes of the spread and increase in intensity of the Wilt disease in recent years.

(6) Control Measures.

Elimination of Sources of Infection.

(1) The possibility of introduction of this disease should be of first importance to the nurseryman in buying stock from outside sources.

(2) Contamination of the water supply has been proved to exist and may be considered likely in all cases where there are large open reservoirs or the water supplies receive additions from surface drainage.

(3) Wilting plants should be dug up intact, not pulled out by hand. The advanced nature of the lesions which in the case of the root-system have usually been followed by secondary bacterial infections and soft rot before symptoms of Wilt are shown by the top make it extremely difficult to lift the plant without leaving sources of infection in the soil.

Avoidance of Conditions Favourable to the Disease.

(1) A sharp knife should be used for making cuttings since it has been noted that infection of imperfectly callosed surfaces is common. Insertion of cuttings in sand or compost at a depth greater than $\frac{1}{4}$ inch is unnecessary for purposes of rooting and increases the risk of collar rot. Rooted cuttings should be potted carefully to avoid injuries to the young roots.

(2) When planting in beds, shallow rather than deep planting is preferable. The Carnation does not produce adventitious roots readily and isolated cases of collar rot have frequently been associated with over-deep planting.

(3) Considerable variation exists in the rate of growth and water requirements of different varieties. If, when watering, differential treatment is neglected, conditions of excessive soil moisture favourable to the disease easily arise. Topsy is the variety that suffers most in this way.

Rotation of Crops.

Rotation of crops has been suggested by a previous writer as a control measure for the Wilt Disease. In this country the most suitable glasshouse crop for this purpose would be Tomatoes. The isolation of *Fusarium culmorum* pathogenic to Carnations from the roots of Tomato plants grown in houses at the Experimental Station in which no Carnations have ever been introduced suggested this rotation to be of little value.

Soil Sterilisation.

The outbreak of the disease in large areas which remain infected for a considerable time makes some form of soil sterilisation a necessity. The effects of chemical sterilising agents on Wilt diseases caused by other *Fusaria* and comparable to that under discussion in the present paper are far from encouraging. Steam sterilisation on the other hand is objected to by many growers on the ground that soil so treated is not suitable for commercial flower-production. Prejudice appears to be the only foundation for their statements and the few growers who have adopted this method of control far from condemning it are enthusiastic and state that increased crops have resulted from its use. It is considered that in the absence of an immune variety, the development and extension of soil sterilisation on commercial carnation nurseries is essential for the proper control of Wilt Disease.

Development of Resistant Strains.

The most satisfactory solution of the Wilt problem is offered by the possibility of the development of strains of the plant immune or highly resistant to the disease. Control of similar wilt diseases has been obtained in America in this way, and there is no reason to doubt that resistant strains of the Carnation could also be obtained.*

Summary.

(1) The Wilt of the Carnation in this country is caused mainly by species of *Fusaria*. These include *F. culmorum*, *F. acuminatum*, *F. anthophilum*, and *F. herbarum*. Different forms of the disease differing in severity follow different types of infection. There is no correlation between the types of infection and the different species causing the disease.

(2) In addition to *Fusaria* isolated from the Carnation, strains of *F. culmorum* from the Aster, Chrysanthemum and Tomato, growing in situations, which had not been occupied at any time previously by Carnations, are pathogenic to the Carnation.

(3) *F. culmorum*, pathogenic to the Carnation, causes Wilt of the Potato and Aster and lesions in the stem of the Tomato.

(4) *F. sporotrichoides*, associated with Carnation Bud-Rot, can also cause Wilt.

* In Table 2 it may be seen that 3 of the original plants shewed greater disease-resistance. Indeed 1 outlived all the replants. This plant as in other cases was a rogue of vegetative habit and commercially useless. Observations suggest this type of plant to be definitely resistant to the wilt disease.

(5) The progress of the disease on commercial nurseries is most rapid on the root disease type of infection where the soil becomes infected over relatively large areas. It is relatively slow in cases of aerial infection of cut stems where the damage caused is of little commercial importance.

(6) The sources of infection on commercial nurseries are dispersion of spores by air currents, water supply contamination, contamination of the soil and there is strong probability that the pathogen exists in virgin soil.

(7) Infection occurs, in nearly all cases, by way of a wound or injury. An account is given of the main positions of infection and the ways in which injuries arise at these points on commercial nurseries.

(8) The period of maximum wilt occurs during the months of high temperature from April to August. Excessive soil moisture and atmospheric humidity favour the disease.

(9) The negative results obtained from soil inoculations on plants grown under conditions making for healthy root action and the effect of high temperature and excessive soil moisture on the progress of the disease suggest that outbreaks of the disease in epidemic form may in some cases be attributed to environmental conditions.

(10) Variation in constitutional resistance of the same variety propagated on different nurseries is suggested as an explanation of the fact that varietal susceptibility differs markedly on different nurseries.

(11) The elimination of outside channels of infection, such as the importation of infected stock or a contaminated water supply, the avoidance of environmental conditions favourable to the disease, of injuries to the plant that increase the risk, and selection of a healthy stock in propagation, are recommended as the principal measures of control. Rotation of crops, as practised by the alternation of Carnations and Tomatoes is considered of little value. The possibility of the development of a strain resistant or immune to the disease offers the best solution of the Wilt problem.

4. Entomological Investigations.

1. Red Spider Investigations.

(a) Reactions of the Hibernating Mite to Temperature and Light.

E. R. SPEYER.

In February, 1928, experiments were carried out with a view to obtaining some information as to the manner in which the adult female mites behaved under influence of temperature and light.

For the purpose a large glass tube, 39 inches in length and 1 inch in diameter was inserted through a hole cut in a pane of glass in the side of a heated glasshouse, so that one end of the tube projected into a warm atmosphere within the house, and the other into a cold atmosphere outside. The mites were introduced into the tube which was plugged at both ends with cotton-wool.

At 3 p.m. on February 15th, the temperature within the extremity of the warm portion was 75° F., and within that of the cold portion 56° F. Forty mites, placed on a small piece of paper, were pushed to the centre of the tube, at the junction of the warm and cold portions. At 4.30 p.m., 9 mites had wandered to the warm portion and 14 into the cold, leaving 17 at the junction. At 9.30 a.m., on February 16th, 2 mites were at the extremity of the warm portion, 31 at the junction, and 7 in the cold portion (4 at the extremity).

The tube was now withdrawn into the glasshouse, so that only 9 inches projected into the cold air, 34 mites being situated in the warm portion, 1 mite at the junction and 5 mites in the cold portion of the tube. By 3.15 p.m., 4 mites had moved into the cold portion. During the night, there was a general movement of the mites to the junction between the warm and cold portions of the tube, as many as 12 being still situated in that region at 10 a.m. on February 17th, when the sun shining upon the warm portion of the tube had attracted 9 mites to its extremity, the short cold portion being in the shade. It was seen from these observations that there was some tendency for the mites to congregate at night at the junction of the hot and cold portions of the tube when the temperature was in the region of 50°F., and during the day to pass to the cooler end of the tube, given equal illumination, but if sunlight fell upon the warm portion, the mites would then pass into the warmth.

Further observations were now made, using dark paper to surround certain portions of, or the whole of the tube in which a fresh assembly of mites were confined. Mites situated at a distance up to 3 inches on either side from the point where the tube passed through the pane of glass were recorded as being "at the junction" between the warm and cold portions of the tube. For convenience sake, the records are set out as if each had been a separate experiment, though the mites used throughout were the same and the observations continuous over 9 days.

Experiment 1.—23 in. tube in warmth, darkened; 16 in. tube in cold, darkened.

At Start	17.11.28	4.30 p.m.	Extremity of warm portion	18 mites	Extremity of cold portion	13 mites
	18.11.28	9.30 a.m.	Warm portion	6 "	At junction	14 "
					Cold portion	11 "

Experiment 2.—As in Experiment 1, but 6 in. at extremity at warm portion exposed to *sunlight*; rest of tube dark.

At Start	18.11.28	9.45 a.m.	Warm portion in light	3 mites	In dark	3 mites
	"	12. 0 p.m.	"	11 "	"	3 "
	"	1. 0 p.m.	"	23 "	"	0 "
At Start	"	9.45 a.m.	At junction	14 "	Cold portion	11 "
	"	12. 0 p.m.	"	7 "	"	10 "
	"	1. 0 p.m.	"	0 "	"	8 "

Experiment 3.—25 in. tube in warmth, darkened; 14 in. tube in cold, exposed to light during daytime.

At Start	18.11.28	1.15 p.m.	Warm portion	18 mites	At junction	0 mites
	20.11.28	11. 0 a.m.	"	5 "	"	15 "
	21.11.28	10.30 a.m.	"	2 "	"	18 "
At Start	18.11.28	1.15 p.m.	Cold portion	8 "		
	20.11.28	11. 0 a.m.	"	6 "		
	21.11.28	10.30 a.m.	"	6 "		

Experiment 4.—24 in. tube in warmth, darkened; 15 in. tube in cold, exposed to *sunlight*.

At Start	21.11.28	12. 0 p.m.	Warm portion	24 mites	At junction	2 mites
	"	3.30 p.m.	"	2 "	"	0 "
At Start	21.11.28	12. 0 p.m.	Cold portion	0 mites		
	"	3.30 p.m.	"	21 "		

Experiment 5.—17 in. tube in warmth, exposed to *sunlight*; 20 in. tube in cold, darkened; 2 in. tube at extremity, exposed to *sunlight*.

At Start	22.11.28	10.30 a.m.	Warm portion	0 mites	At junction	9 mites
	"	1. 0 p.m.	"	2 "	"	5 "
	"	3.30 p.m.	"	5 "	"	7 "
At Start	"	10.30 a.m.	Cold portion in dark	14 mites	In light	0 mites
	"	1. 0 p.m.	"	8 "	"	8 "
	"	3.30 p.m.	"	3 "	"	8 "

Experiment 6.—17 in. tube in warmth, darkened; 20 in. tube in cold, darkened; 2 in. at extremity exposed to *sunlight* during daytime.

At Start	22.11.28	3.30 p.m.	Warm portion	5 mites	At junction	7 mites
			Left during 23.11.28.			
	24.11.28	12. 0 p.m.	Warm portion	0 "	At junction	5 "
	22.11.28	3.30 p.m.	Cold portion in dark	3 "	In light	6 "
	24.11.28	12. 0 p.m.	"	3 "	"	13 "

The following conclusions may be drawn from the foregoing observations :—

- (a) In absence of light or in feeble illumination, the mites tended to congregate at the junction of the warm and cold portions of the tube, *i.e.*, when the temperature was in the region of 50°F. (Experiments 1 and 3). If placed in the warmth, they moved to a cooler portion of the tube.
- (b) In the presence of sunlight the mites become very active, whether in the warmth or the cold. They were definitely attracted to portions of the tube illuminated by sunlight, both in the warmth (Experiments 2 and 5) and in the cold (Experiments 4 and 6).
- (c) When both warm and cold portions of the tube received sunlight, there was a tendency for rather more mites to collect in the cold than in the warm portion (Experiment 5).

The conclusions are borne out by observations made during the winter months in glasshouses in which very large numbers of mites are hibernating. On any sunny day, even if frost is registered, the mites become active, and ascend pillars, posts and rafters towards the light from the hiding places behind pipe-hooks and in crannies of the gutter woodwork. When the pipes are first heated, there is a tendency for the mites to move upwards in order to obtain a cooler temperature, and they only descend again to the plants when they are ready to lay their eggs.

(b) Petroleum Emulsions.

E. R. SPEYER.

Emulsions of comparatively heavy petroleum of specific gravity about 0.86, pure as far as the absence of more than traces of sulphur, products of oxidation, and unsaturated hydrocarbons are concerned, have now come into general use for the control of red spider mite upon tomato and cucumber plants.

A young cucumber plant from the propagating house, severely infested with the mite, was sprayed at the end of January with such an emulsion used at a strength of 1 part in 80 parts water by volume, the stock concentrate consisting of 81.8% petroleum, 4.5% potash soft soap, dissolved in 2.2% fusel oil and 11.5% distilled water.

On the eighth day after spraying, 7 adult females, 3 adult males, 29 nymphs, and 2 larvae, a total of 41 mites, were dead upon the lowest leaf of the plant. On this leaf were also 20 eggs which were kept under observation for another 3 days, when the

rest of the leaves were examined. Upon the latter 2 adult females and 2 larvae were dead, while 4 larvae were alive. In all, there were upon the foliage 49 unhatched eggs which, having been laid at least 11 days' previously, are assumed to have been destroyed. This gives a 100% kill of mites, and a 92% kill of eggs.

Such a high mortality cannot be expected when spraying upon a commercial scale. Uninfested cucumber pot plants were sprayed with the same emulsion, and adult female mites placed upon their foliage 3 days after application. No eggs were laid upon the plants until 10 days after application of the spray.

Other plants sprayed with the same petroleum emulsified with soft soap and calcium caseinate at a strength of 1 in 80 showed a similar lapse of time between application and the laying of eggs by the mite, and it was noticeable that they had grown taller by $1\frac{1}{2}$ inches than untreated control plants.

The increased growth is probably due to the prevention of evaporation from the leaf surface caused by a deposition of oil upon the latter. Whereas such conditions may be favourable to the growth of the cucumber plant, diseases of the tomato plant such as "Dropsy" of the foliage, and *Botrytis*-rot of the stem and truss may be greatly aggravated by the application of petroleum emulsions, though they do not appear to be actually caused by the application. After spraying, which should not be carried out upon the same plants more frequently than once in three weeks, especial care should be taken that tomato plants do not receive a surplus of water, either at the root or upon the foliage, and that good ventilation is given.

Formulas for the preparation of petroleum emulsions are given elsewhere in this report, together with observations made upon commercial nurseries.

(c) Experiments on Commercial Nurseries.

O. ORCHARD.

Cleaning of Glasshouses Before Planting.

The methods available for cleaning empty glasshouses are (1) scrubbing the superstructure with soap and water, followed by the application of water through a hose. (2) spraying with either cresylic acid and water, or emulsified cresylic acid. (3) spraying with emulsified oil and (4) fumigation with naphthalene. The first two of these were examined in 1927, and discussed in the Annual Report for that year. The others have been investigated during the past year. Mr. J. C. Copley and Mr. C. J. Randall very kindly provided houses for the experiments.

A large tomato house, previously used for propagating and heated since January 9th, where large numbers of the hibernating mites had been found, was sprayed on February 13th with an oil emulsion, using a power sprayer and covering the whole of the woodwork, glass, etc. The superstructure was examined on February 17th and many mites were found fixed to the woodwork by the oil emulsion. The following figures are taken from counts made on that portion of the bars between the top of the purlin posts and the ventilator seatings.

Post number.	1	2	3	4	5	6	7	8	9
Number of mites.	18	17	13	7	22	8	10	24	25

It was considered unnecessary to make further counts because the dead mites could be found on practically every bar in the house. When examined a few days later, no living forms could be found.

Between January 5th and January 31st, fifteen low cucumber houses, which were to be used for propagation purposes, were fumigated by vaporising from lamps, one pound naphthalene per 1000 cubic feet. The temperature was kept as high as possible during fumigation, 70°F. being the minimum. In all cases, the houses were heated one week prior to fumigation, as at this time of the year the mite does not leave hibernation until about seven days after the heat is applied. The object of these fumigations was to kill the mites after they had left their winter quarters, and before they dropped down to the plants. Although the results obtained were very satisfactory, large numbers of the mites were found beneath the outside hinges of the ventilators after fumigation. So far, it has been impossible to counteract this important source of infection.

As a comparison, on the same nursery, the superstructure of twenty houses was sprayed with oil emulsion about one week after starting the boilers and just before planting. Seven control houses were left unsprayed.

Mite infestation occurred in the houses treated with naphthalene, or sprayed with oil emulsion, much later than in the control houses, and consequently, the plants in these houses did not require so much spraying during the season. There was no difference between those houses treated with naphthalene and those treated with oil emulsion, judged on the basis of first appearance of the mite and extent of infestation.

Oil Emulsions as a Means of Summer Control.

During the past season, the value of oil emulsions as a preventative against attack by the spider mite, during the early life of the plant was tested. Mr. J. C. Cobley generously gave permission for extensive experiments to be conducted on one of his

nurseries. The experiment commenced on February 23rd, when many thousands of tomato plants in size 60 pots were sprayed with an oil emulsion diluted to 1 in 80. By the 27th February, all plants more than one month old had been sprayed. During the third week in March the plants in nine houses were sprayed for the first time after planting, a few mites having been found feeding. This application proved very efficacious, but the plants were again sprayed on the 3rd May as a further preventative. Owing to the varied amount of work which must necessarily be carried out on nurseries at this period of the year, it was not possible to spray again until the 2nd July, by which time the mite had spread fairly freely on many of the plants. A fourth application on July 26th was very successful in controlling the pest, only one other spraying on August 18th being necessary to keep the plants exceptionally free of the mite during the whole of the season.

It was not found necessary to spray any houses on the nursery more than five times, and in many cases two applications proved effective.

Four other nurseries were used in conjunction with the above and in every case it was definitely shewn that the early sprayings applied immediately after planting out, were considerably more effective in controlling the pest than those applied later in the season. Observations on a great number of nurseries in the district show that it is a mistake to wait until spider damage is apparent, as by that time the mite has become more securely established than is generally realised and is correspondingly more difficult to control.

Age of Tomato Plant in Relation to Spider Mite Infestation.

Experiments have been conducted throughout the year to ascertain if the susceptibility of tomato plants to attack by the spider mite is determined by the age of the plant.

For this purpose six groups of seven plants each were grown in 12-inch pots and given normal cultural treatment, so that by June 1st the oldest plants were six months and the youngest, one month old. At this time the forty-two plants were equally infested with the mite by placing badly attacked plants among them. Twenty-one days later the youngest batch of plants was badly infested with the mite and shewed feeding marks on all the leaves. The other plants were less seriously damaged, those six months old shewing very little damage at all, as the mite at once left the leaves with which it had first come into contact and moved to the younger growth. No attempt was made to control the pest, and at the end of the season it was found that the plants most badly damaged were those infected between the ages of one and three months. From the beginning of the experiment, the four, five and six months

old plants were never materially damaged, whereas the younger plants were unable to grow away from the mite. These results bear out observations on nearly all nurseries visited this season. By far the best control of the mite was obtained where, when the pest was found, the plants were sprayed at the age of two to four months with an oil emulsion.

Movement of the Hibernating Spider Mite from the Superstructure of Glasshouses.

Numerous observations have been made under various conditions to obtain some information with regard to the time of movement of the mite in early spring.

On November 23rd, 1927, one hundred hibernating forms of the mite were placed in a cavity behind a large iron hinge, and screwed to a board. A band of tanglefoot was placed around the hinge leaving sufficient room to allow the mite to leave the latter, and yet be instantly trapped. The trap was then fixed to the roof, outside a glasshouse.

On January 16th, 1928, the mites found behind a ventilator hinge were treated in the same way, and both were examined periodically for movement of the mite. No movement occurred in either trap until February 24th, when a number were found stuck in the tanglefoot, and following this the mites came out rapidly until March 13th, when, on removing the hinges, only a few dead forms were found. A number of hinges sealed in the same way on commercial nurseries, confirmed the above observations for in all cases, the mite moved from this place of hibernation during the last few days of February.

During the repairing operations on commercial nurseries many parts of the woodwork were found to be sheltering hibernating mites. Several such pieces were brought to the Station and screwed to rafters inside a glasshouse in the same positions as originally found, and a band of tanglefoot placed around each. Movement occurred at about the same time as from the hinges outside, and the figures obtained from one may be of interest. On February 16th, twelve mites were trapped in the tanglefoot, and by the 27th, the number increased to one hundred and twenty. Movement then ceased, and on removing the woodwork, it was found that all the mites had left.

During the first week in March a band of tanglefoot was placed around the edges of six boards, five feet square, which were suspended on wires in a house immediately below the ridge, which had harboured large numbers of spider as late as February 15th. These boards were examined at intervals of a few days until April 12th, but only four mites were trapped on one board during the first two days.

The above experiments compare favourably with observations on many nurseries in the district, shewing that the great majority of mites leave hibernation by the end of February. They are found leaving the ridge-capping and outside hinges, only to enter the glasshouses by means of cracks in the ridge. As an experiment, the inside ridge-board of a house was painted with a thin mixture of tanglefoot, but although numbers of mites were caught, under present conditions this method of trapping the spider mite cannot be recommended owing to the difficulty of obtaining material which is sufficiently sticky and which can be easily applied.

Early in December, 1927, rolls of corrugated paper, which serve so well as traps during the autumn, were placed in various positions in three houses on two nurseries. The traps were continually examined, and although the mites were found in great numbers over the woodwork of the house during February, 1928, none were trapped in the paper until the following November. It appears therefore that once the mites leave hibernation, under normal conditions they cannot be induced to hibernate again as they at once move in search of food.

Although it is well known that every available crack and joint in the superstructure of a glasshouse must be regarded as a probable hibernating quarter for the spider mite, it is doubtful if many realise the numbers actually hidden away. The following figures obtained from the observation of four traps on each of four purlin posts are instructive: In house No. 1 bands of tanglefoot were placed (1) at the junction of the purlin and supporting post, (2) at a place about eighteen inches from the roof where a cross batten was fixed to the side bars to carry trailing wires, (3) at the junction of the base of the post and the dolly, and (4) at the base of the dolly on which the post stands. The bands were placed in position on November 25th, 1927, and reference to the following tables will give the dates of examination of the traps, the number of mites trapped, and the period of greatest activity.

Post No. 1.

Number of Trap.	Number of Mites in Trap.			
	1	2	3	4
Nov. 25th ...	0	0	0	0
Dec. 11th ...	6	0	0	0
Jan. 10th ...	10	0	0	0
Jan. 15th ...	72	0	0	0
Jan. 31st ...	72	0	4	24
Feb. 1st ...	72	0	4	24
Feb. 3rd ...	72	0	6	30
Feb. 8th ...	72	0	6	31
Feb. 11th ...	72	0	6	32
Feb. 17th ...	72	0	6	32

Post No. 2.

Number of Trap.	Number of Mites in Trap.			
	1	2	3	4
Nov. 25th ...	2	0	0	0
Dec. 11th ...	2	0	0	0
Jan. 10th ...	6	0	0	0
Jan. 25th ...	33	0	0	0
Jan. 31st ...	33	4	28	0
Feb. 1st ...	33	4	28	0
Feb. 3rd ...	33	5	28	4
Feb. 8th ...	33	35	28	10
Feb. 11th ...	33	35	35	17
Feb. 17th ...	33	35	35	17

On both posts, trap No. 1 was at the top and it is interesting to note that in both cases the mite moved from that position before it did from the others. In the same house, bands of tanglefoot were placed on the rafters between the top of the purlin post and the ridge board, in such a position that it was possible to observe the direction in which the mite moves on first leaving hibernation. These observations show definitely that when the mites leave hibernation the main tendency is to move to the top of the house. Although in this house tomato seedlings in boxes were standing on the soil, the mites were found to leave the base of the purlin post and move up into the roof and sunlight. Within a very few days the mites dropped from the roof to the soil, and quickly reached the plants.

In house No. 2, early in January large numbers of the mite were found in a tomato house behind the batten which supports the tie-wires, and where it is attached to the purlin post. Bands of tanglefoot were placed around two posts on January 17th, the number of mites trapped being tabulated in the accompanying table.

House No. 2,

Date Examined.	Number of Mites Trapped.	
	Post No. 1.	Post No. 2.
Jan. 20th ...	34	41
Jan. 23rd ...	34	41
Jan. 26th ...	34	61
Jan. 31st ...	144	126
Feb. 3rd ...	170	138
Feb. 11th ...	225	230
Feb. 15th ...	326	280

House No. 1 was first heated on January 9th, and No. 2 on February 13th. On examination of the above tables, it is interesting to note that in each house the majority of the mites left hiber-

nation at about the same time, and that the heating of the house was not the main cause of movement. It is obvious therefore that sun-heat and light are important factors governing the movement of the mite from hibernation in the early Spring.

The Effect of Some Cultural Conditions of the Tomato Plant and Spider Mite Infestation.

Effect of Manurial Treatment.

Observations were carried out during the past season to ascertain the reaction of tomato plants with various manures, to infestation by the spider mite. On May 10th, eighteen tomato plants (Kondine Red), were planted in baked soil in twelve-inch pots, and divided into six series of three each. To obtain the required type of growth, the following manures were incorporated with the compost, and continually applied as top dressings during the experiment : (1) dried blood, (2) sulphate of potash, (3) superphosphate, (4) a balanced mixture of dried blood, superphosphate and sulphate of potash. Series (5) was unmanured, and (6) received stable manure and was used as a control.

The eighteen plants were infested with the spider mite on June 1st by placing heavily infested tomato plants among them. These were removed after three weeks, and a fortnight later every plant was completely covered with the pest, the rate of spread having been equal for each type of growth. The three control plants appeared to be rather more infested than the rest of the series, but this was undoubtedly due to the fact that they possessed the greatest leaf surface. It should be noted that the manures in each case were used to excess so as to obtain the growth required. As was expected, growth was not so good under these conditions as under normal conditions. The experiment was continued until the end of the season, but at no time was there evidence that a particular manure has any effect in inducing resistance to spider mite attack.

A second series of plants treated in the same manner and grown in conjunction with the above, but a fortnight later, confirmed the above observations.

Effect of High Water Table in Soil.

It has been suggested that the high water table present in the soil during the Spring on some low-lying nurseries, might possibly weaken the constitution of the tomato plant, and so indirectly assist the spread of the spider mite. Accordingly the following experiment was conducted :—

During the first week in March nine tomato plants (Kondine Red), were potted into twelve-inch pots, using normal compost. Six plants were given no drainage, three of them being fitted with

a piece of glass tubing to act as an overflow pipe, so that the water level was maintained at seven inches below the surface, while three were fitted in the same manner and the water level maintained at three inches below the surface. The remaining three were given the usual drainage and used as controls.

On the 27th March, when the plants had become established, the water was raised to the required levels and maintained during the whole of the experiment. All nine plants were then infested with spider, by placing small infested plants amongst them, and on April 19th the numbers of leaflets showing feeding marks were counted and marked. The rate of spread of the mite over the plants was determined by counting the marked leaflets each subsequent week until May 25th. At this time practically all leaflets on all plants were infested with the mite. As was to be expected, the control plants grew much faster and taller than the other six, and although the number of leaflets infested was slightly greater on the control plants, it seems that as all nine were equally infested over their whole available leaf surface, excess of water at the roots does not render the tomato plant more susceptible to spider attack.

One plant, having the water level three inches below the surface, died on July 9th, a second one dying on July 28th. The remaining seven continued until the end of October, but at no time during the season were the water-logged plants found to be more susceptible to the spider mite than the control ones.

The Effect of Damping Tomato Plants with Water in Relation to Red Spider Mite Attack.

To determine whether the mite breeds more freely on tomato plants which are not damped overhead, than on those which are damped daily, ten plants in size 60 pots were infested with the mite on April 14th by placing them in contact with spider infested plants.

Nine days later, the number of leaflets on each plant which shewed feeding marks were counted. The ten plants were then divided into two series, there being two plants of the variety Ailsa Craig, two of E.S.1, and one of Kondine Red in each series. One group was damped overhead daily with a hose. The experiment was continued for five weeks during which time the plants were potted into size 32 pots. The rate of increase of the mite was determined by the number of leaflets shewing feeding marks, these being counted once every week. At the end of the experiment both series of plants were equally badly infested, shewing that the application of water under ordinary damping operations has a negligible effect.

Conclusions.

Of all methods used in the control of the red spider mite on tomatoes during the past season, spraying with oil emulsions has proved the most effective. Experiments have shewn the most successful results on nurseries where the first application was made when the plants were about three months old, and further sprayings given at intervals of three to four weeks, until the first week in September. Under ideal conditions, plants sprayed periodically at intervals of three to four weeks, and grown side by side with spider infested plants, remained free of the pest during the whole of the season. A good power sprayer should be used, and the emulsion applied after trimming the foliage.

Experience has shewn that when plants are sprayed during April and May, some care is required. At this period of growth the atmospheric conditions of glasshouses, combined with the thick foliage of the plants, are favourable to "Dropsy" and *Botrytis*, and in a few cases it was found that unless overhead damping was withheld for a few days and the atmosphere of the houses kept drier than usual the application of oil emulsions had a tendency to aggravate these troubles. Therefore, it is important that, during the early season, spraying with these emulsions should only be carried out during bright sunny weather, and overhead damping should be withheld for three days after application.

(d) Fumigation Experiments.

W. H. READ.

The investigations commenced in 1927, have been continued and many compounds have been examined regarding the effect of their vapours on both the Red Spider mite and upon plants. Substances found to exert a decided action upon the mite were tested under all possible conditions of humidity, temperature, light, duration of fumigation, etc. In several cases the plants were more seriously damaged when the fumigant was evaporated rapidly than when the vaporisation was slow.

As in previous tests, many of the substances examined destroyed all the mites exposed to their vapours in low or moderate concentrations; *i.e.*, 2-5 ozs. per 1000 cu. ft., but so far tests have failed to indicate any compound which can be employed as a fumigant without serious damage to plants with the possible exception of 2 chloro p. nitrotoluene (see p. 91). In the case of several substances the concentrations required to give a complete

kill of the mite at low temperatures were determined with a view to their adoption as winter fumigants although they severely injured plants when used in amounts sufficient to control the pest at higher temperatures.

The results of these tests are summarised in the following table :—

TABLE A.

Substance.	Amount Employed. Ozs. per 1,000 cu. ft.	Temp. °F.	Duration of Fumigation in hours.	NOTES : Effect on Mites and Plants.
Chloro-benzene	10	60	8	Mites anaesthetized but 100% recovered in 24 hrs. with 10 ozs. at which concentration plants were damaged.
Bromo-benzene	10	70	8	Effect on mite as above. Damage to plants more serious.
Iodo-benzene	10	70	8	No mites killed. Damage to plants less than with chloro- and bromo-benzenes.
Dimethyl-aniline	6	70	8	Mites not killed with 6 ozs. Plants seriously damaged 3 ozs.
o-Chloro-aniline	2	70	5	Mites killed. Active stages killed with 2 ozs./1,000 cu. ft. Plants badly damaged with 2 ozs.
s-trichloro-aniline	2	70	5	Good distribution could not be obtained on a large scale as the vapour condensed rapidly, forming aggregates of minute crystals. Plants in the immediate vicinity damaged. See Annual Report, 1927.
Ethyl p-nitro-benzoate	2	80	5	Plants injured. Distribution inefficient.
Ethyl p-nitro-benzoate 50%, camphor 50%	3	70	5	Mites killed. Plants badly burned.
Acetophenone	4	80	6	Mites killed with 4 ozs. Plants completely defoliated by 2 ozs./1,000 cubic feet.
Benzoquinone	2	80	6	Mites killed. Eggs not destroyed. Plants killed.
Chloronitro-benzene	3	60	18	"Active" stages of mite killed. Severe scorch; plants damaged by 2 ozs. for 7 hrs. especially if dry at the root. Mites not killed with 2 ozs.

Table A (continued).

Substance.	Amount Employed. Ozs. per 1,000 cu. ft.	Temp. °F.	Duration of Fumigation in hours.	NOTES: Effect on Mites and Plants.
2 : 5 dichloro-nitro-benzene	3	70	6	Mites not killed. Plants damaged as with monochloro nitro-benzene.
O. and p-chloro-toluene	10	70	6	Mites not killed. Plants damaged slightly. No damage with 5 ozs. per 1,000 cu. ft.
p-nitro-toluene	3	70	6	Mites not killed. Plants badly injured.
o-toluidine	3	60	6	Mites not killed. Plants not injured.
2 chloro p. nitro-toluene	3	65	8	Mites killed. Damage to plants slight under favourable small-scale conditions. <i>See</i> later.
Chloro-naphthalene	10	65	6	Mites killed. Plants killed when rapidly evaporated, but not when very slowly evaporated, under which conditions mite is not killed by 10 ozs. in 8 hrs.
Tetrachloro-naphthalene	5	65	8	Mites not killed. Plant scorched probably due in part to the hydrochloric acid formed when the substance is rapidly volatilised.
Xylidine ...	4	70	6	Mites killed. Plants slightly damaged. 90% killed with 5 ozs. to 1,000 cu. ft. in 8 hrs. at 60°.
Pyridine ...	6	70	20	Not more than 15% of adult "active" stages and 40% "active" young stages of mite killed. Plants destroyed.
Quinoline ...	3	70	11	Active stages killed. Plants seriously damaged. Mites all killed by 5 ozs. but not by 3 ozs. in 7 hrs. at 70°.
Nicotine ...	4	80	7	Mites practically unaffected.
Thymol ...	1½	70	10	Almost complete mortality of mites. Plants badly burned when thymol is rapidly evaporated.
Furfurol ...	2	65	10	All mites killed. Severe injury to plants with rapid evaporation.

Table A (continued).

Substance.	Amount Employed Ozs. per 1,000 cu. ft.	Temp. °F.	Duration of Fumigation in hours.	NOTES: Effect on Mites and Plants.
Essential oil of camphor	4	75	8	Mites unaffected. Plants destroyed.
Oil of cloves ...	2	65	5	As above.
Paraffin volatilisation	2	65	5	Mites killed. Plants injured due to oxidation of oil. See later.
Formaldehyde 40% solution	20	70	10	Mites unaffected.
Ethylene dibromide	4	70	10	Majority of mites killed. Plants injured by rapid volatilisation. Mites not killed and plants uninjured by 2 ozs.
Monomethylamine	4	70	6	Mites not killed. Severe scorching of plants.

Where a 100% kill of mites was not obtained the amounts referred to in the above Table are the maximum amounts employed in the series of tests with the substance in question.

The above results were obtained by small scale experiments under strictly controlled conditions, using mite-infested tomato plants with the second truss flowers about to open. Previous work has shewn that at least double the amount of a fumigant is required to yield the same degree of control in commercial houses as in laboratory tests, so that the majority of substances tested would be valueless under commercial conditions on account of their expense.

Several substances were more fully examined, however, with the following results:—

2 : 4 Dichloroaniline.

It has been found (Annual Report, 1927) that relatively small amounts of dichloroaniline were effective in destroying the mite when vaporised with a lamp. These experiments were continued and while on a small scale 2 ozs. to 1000 cu. ft. gave complete control of all stages other than eggs without greatly injuring tomato plants provided they were dry at the roots, it was impossible to obtain a control on a large scale without seriously injuring the plants.

This was largely due to the excessive deposition of dichloroaniline on plants in the vicinity of the lamp and at the top of the chamber.

2 Chloro p-nitrotoluene.

The volatilisation of 2 ozs. to 1000 cu. ft. of the above was found to control the mite in 16 hrs. at 60°F. with but slight injury to tomato plants. Using 3 ozs. the same result was obtainable in 8 hrs. at 65°, causing a slight scorch of the leaf tips and sepals. Tests on a large scale have been commenced.

Thymol.

Amounts of thymol as small as 1 oz. to 1000 cu. ft. were found to give an almost complete control of "active" stages of the Red Spider mite in 6 hrs. at 70°F. when vaporised. In view of the effect on plants which are practically killed by 1½ ozs. to 1,000 cu. ft., thymol cannot be recommended as a fumigant for growing plants whilst its excessive cost renders it impossible as a winter cleansing agent.

Furfurol.

Furfurol resembles thymol in its action on plants. 2 ozs. to 1000 cu. ft. killed 100% of mites when volatilised and 4 ozs. poured on the floor of a chamber in small scale test had the same effect, but in experiments on a larger scale it proved less efficient than naphthalene.

Vaporisation of Paraffin.

Attempts to control the mite by the volatilisation of a highly refined, heavy paraffin failed owing to the oxidation of the oil which yielded substances, probably aldehydic in nature, highly injurious to plants, though a great deal more effective in controlling the mite.

The oil employed was a sample which when emulsified can be safely sprayed on the living plant. Before vaporisation it was odourless, free from acid and non-reactive with potassium permanganate or bromine in glacial acetic acid, but a portion obtained by distilling the oil (B.Pt. 340°C. upwards) in a current of air at 220°C. had an unpleasant odour and reacted with the above re-agents. When emulsified, this distillate had a very injurious action on plants; whereas a portion obtained by distilling in a stream of carbon dioxide at 250°C. was unaffected, shewing that the injurious action is due to oxidation processes.

Oil Emulsions.

The factors which govern the efficiency of emulsified petroleum oil sprays employed in the control of the Red Spider mite have been investigated and in addition vegetable oils, suitably emulsified, have been tried with promising results,

Petroleum (Paraffin) Oil Emulsions.

The active base of these emulsions is a highly purified petroleum of required boiling point and viscosity and the high cost of such sprays is due to the expensive processes involved in purifying the oil.

Oils possessing different chemical properties have been tried therefore, to ascertain whether a less highly refined oil might not be employed on tomatoes under glass. For this purpose a standard process of emulsification was adopted, yielding an emulsion of the following composition :—

<i>Oil</i>	75 parts by weight.
<i>Water ...</i>	10 parts by weight.
<i>Soft Soap</i>	2 parts by weight.

The soap employed in these standard emulsions was ordinary horticultural soft soap, but other soaps such as sodium palmitate and stearate, potassium palmitate and stearate, and sodium cocoanut oil soap have been used successfully. Emulsification with calcium caseinate was difficult but the stability of stock soap-formed emulsions was improved by stirring in 5—10 cc. of 10% sodium caseinate solution.

The process of emulsification consisted in dissolving the soap in the water, adding to this an approximately equal amount of the oil and stirring vigorously until a smooth white cream was obtained when the remainder of the oil was added little by little with constant stirring until the whole had been added ; the stirring being continued until a smooth, uniform emulsion was obtained. In

Table 1.
Properties of Oils Tested.

No. of Sample.	Boiling Point °C.	Specific Gravity.	Unsat. Hydro-carbons %	Aromatic Hydro-carbons %	Unsulphonated Residue %	Acidity in mg. KOH per gm. Oil.	Description.
1	330-360	0.866	(Total	0.5%)	99.5	Nil	" Water-white " paraffin.
2	340-360	0.869	4.0	Nil	96.0	0.325	
3	342-360	0.870	(Total	0.75% approx.)	99.25	Nil	" Water-white " paraffin.
4	340-360	0.886	20	8	72	0.225	Light-lubricating oil.
5	—	0.903	(Total	25.0%)	75	—	Lubricating oil.
6	250-300	0.890	12	52	36	2.29	" Neutral " oils from " low-temperature " tar.
7	300-350	0.981	14	56	30	2.30	
8	205-240	0.812	Nil	8.0	92.0	0.07	Burning kerosene.

Table 2.

Effect of Oils on Plants and Red Spider mite.

No. of Sample.	Dilution.	Effect on Plants.	Effect on Mites (Eggs not included)
1	1 in 80 1 in 100	No damage "	96% killed. 88% killed.
2	1 in 80 1 in 120	Foliage burned where the oil tended to accumulate	98% killed. 90% killed.
3	1 in 80 1 in 100	No damage "	95% killed. 80% killed.
4	1 in 80 1 in 100	Oil-impregnated spots appeared on leaves three days after spraying and died out to leave dead tissue. Slow yellowing and fall of lower leaves two weeks after spraying	90% killed. 65% killed.
5	1 in 80	Slight burning of leaves followed by yellowing and defoliation	
6	1 in 80	Almost the whole leaf area had an oil- soaked appearance one day after spraying. Plant ultimately killed	100% killed.
7	1 in 120 1 in 160	General effects as for above " " "	100% killed Many mites alive.
8	1 in 20 1 in 30 1 in 40	Severe injury to foliage. Oil absorbed into the leaf tissue finally causing burnt patches	Many mites alive in all instances.
	1 in 80	Damage similar to above but much less severe	

The figures for the percentage of mites killed are in the majority of cases the average of a number of counts.

many cases the emulsion so formed had to be more highly emulsified by churning with a syringe since it was found that the oil globules were too large to remain in suspension, even after prolonged stirring and formed a layer of "cream" on the surface of the diluted emulsion.

The chemical and physical properties of the oils were determined experimentally (Table 1) whilst their effects on both the mite and on plants (Table 2) were determined by spraying spider-infested tomato plants with various concentrations of oil obtained by diluting the emulsions with hard water. (Hardness equivalent to approximately 20 degrees.) In order to obtain comparable results several plants were employed for each dilution and were thoroughly drenched with a syringe.

It is seen from results that samples 1 and 3 which are expensive highly refined oils cause no injury to plants whilst sample 2, consisting of a portion of No. 1 which had been oxidised by heating in air, caused damage to foliage as did Nos. 4 and 5 consisting of high grade lubricating oils. After removing the injurious principles from the three latter oils by the standard process of purification, *i.e.*, washing with concentrated sulphuric acid, water, caustic soda and water consecutively and finally distilling in an atmosphere of carbon dioxide, the resulting products were similar to Nos. 1 and 3 both in chemical properties and in their non-injurious action on plants.

From the above results there appears little likelihood of appreciably reducing the cost of petroleum oil emulsions having a "heavy" oil as their insecticidal principle by using a less highly refined oil.

The Effect of the Degree of Dispersion on the Stability of Diluted Emulsions.

A series of emulsions were made by the method previously described using varying amounts of horticultural soft-soap solutions of different concentrations with equal amounts of oil (Sample 1), only a portion of each stirred emulsion being churned with a syringe.

The "creaming" tendencies of these emulsions when diluted with 50 parts of hard water (hardness equivalent to approximately 20 degrees) were observed by thoroughly shaking the mixture in a measuring cylinder and allowing to stand for an hour whilst the sizes of the oil globules were determined by measuring them microscopically by the "hanging drop" method.

The results of these tests are described below :—

1. Emulsion made by gradually stirring 8 volumes of petroleum (sample No. 1) into 1 volume of 20% soap solution.

(a) *Stirred only*.—Emulsion was fluid, "creamed" rapidly when diluted but shewed little tendency for pure oil to separate out. Oil globules mostly from $10\text{-}20\mu^*$ in diameter, with about $\frac{1}{3}$ th of the total ranging from $3\text{-}10\mu$.

(b) *Churned with a syringe*.—Emulsion very much less fluid than (a) with less tendency to "cream" on dilution and no tendency for oil to separate out. Oil globules mostly $2\cdot5\text{-}5\mu$ in diameter with a small proportion from $5\text{-}15\mu$ and some less than $2\cdot5\mu$.

* μ —One thousandth of a millimeter,

(2) Emulsion from 8 volumes of oil and 2 volumes 20% soap solution.

(a) *Stirred only*.—Very fluid emulsion which “creamed” immediately on diluting and liberated free oil. Oil globules shew a large variation in size—some were as large as 60μ , the majority about 20μ with some ranging to 2μ in diameter.

(b) *Churned with a syringe*.—Stock emulsion moderately fluid with a slight tendency to “cream” but no oil separation. Not so stiff as 1 (b). Oil globules very uniform about 5μ in diameter with some from 10μ downwards.

(3) Emulsion from 8 volumes of petroleum and 1 volume of 30% soft soap solution.

(a) *Stirred only*.—Diluted emulsion “creamed” very rapidly, was fluid and shewed very little tendency for oil to separate out. Diameter of oil globules ranges from $30\text{--}15\mu$ with a small proportion from $15\text{--}3\mu$.

(b) *Churned with a syringe*.—Stock emulsion very stiff and when diluted, shewed little or no tendency to cream. No oil separated out. Oil globules very uniform in diameter at $4\text{--}2\mu$ with a very few ranging to 10μ .

It was found during the above tests that initiation of emulsification was facilitated by using a small proportion of concentrated soap solution rather than the equivalent amount of lower strength in addition to which the final product was more stable. In all cases the stirred emulsions shew a decided tendency to “cream” due to the relatively large oil globules rising to the surface, and thus would only prove efficient where the diluted spray fluid is thoroughly agitated during spraying operations. The efficiency of the emulsion under such conditions is probably slightly greater than that of “syringed” emulsions on account of the greater rapidity of de-emulsification on coming into contact with the leaf surface.

The preparation of “syringed” emulsions is considered impracticable and it is doubtful whether the small saving resulting from the preparation of stirred emulsions is worth the trouble and time expended in dissolving the soap, etc.

A further point of interest is the decrease of fluidity with increased dispersion of the oil and in consequence, the idea that the “thickness” of an emulsion is an index as to the amount of active oil it contains is erroneous.

Vegetable Oil Emulsions.

In view of the necessarily high cost of highly refined petroleum oils, tests have been made with emulsified vegetable oils. Preliminary experiments have shewn, however, that several of these oils possess slightly greater insecticidal values than the highly refined petroleum oils and also that they are more easily emulsified. It will be necessary to investigate still more fully their effect on plants at all periods of their growth and under varying climatic conditions, before definite recommendations can be made.

2. A White-Fly Parasite (*Encarsia formosa* Gahan.).

E. R. SPEYER.

The Chalcid Wasp which parasitises the Greenhouse White-fly (*Trialeurodes vaporariorum* West w.) was bred successfully through the winter in the special breeding house provided by the Empire Marketing Board.

Distribution of the Parasite.

As early as February it was found possible to begin the distribution of parasites to growers and nurserymen. Black scale of the white-fly containing the parasite upon tomato foliage were sent out in cardboard boxes with printed directions in each case. Owing to the great numbers of parasitised scales upon the foliage, an accurate record of the number of parasites sent out could not be obtained, but the following figures give an approximate and conservative estimate of the number bred and distributed for each month of the growing season of 1928 :—

February	...	...	8,700
March	...	...	1,300
April	...	...	37,000
May	...	...	44,000
June	...	...	48,000
July	...	...	96,000
August	...	...	25,000
September	...	...	27,000
TOTAL			287,000

Of these, the following estimated numbers were sent to growers: in Hertfordshire, 112,000; Sussex, 44,000; Gloucestershire, 13,000; Essex, 10,000; Derbyshire, 10,000, and smaller numbers to Cambridgeshire, Norfolk, Lincolnshire, Yorkshire, Glasgow, North Wales, Warwickshire, Dorsetshire, Devonshire, Hampshire, Surrey and Middlesex.

In addition to these, the Royal Botanic Gardens at Kew received some 10,000 parasites in May, and a further consignment of some 25,000 in September.

In June, some 22,000 were sent to the parasite laboratory at Farnham Royal for shipment to Canada. 14,000 were distributed mostly through the Guernsey Growers' Association to nurserymen in that island, these having been sent over in May. Smaller consignments were distributed to the School of Botany, Cambridge, The John Innes Institute at Wimbledon, The Swanley Horticultural College, Kent; Studley College, Warwickshire; the South-Eastern Agricultural College, Wye, and University College of North Wales.

The Royal Tunbridge Wells Gardeners' Society and the Derbyshire Education Committee gave valuable assistance in distributing the parasite to local growers in their respective districts.

Method of Breeding and Distribution.

Tobacco plants in pots were used to breed a stock of White-fly comparatively free from the parasite. The foliage of the plant, as well as that of Abutilon, Bouvardia, Datura, Eucalyptus, Heliotrope, and Scented Geranium, appear to repel the parasite. With these tobacco plants, young tomato plants in pots were continuously grown through the season so that a constant supply of white-fly and parasite were available.

The main distribution was made from 95 large tomato plants in pots and 140 tomato plants grown in the ground. Whereas the former 95 plants supplied some 115,000 parasitised white-fly scales, from April 27th to August 10th, the 140 planted in the ground in February gave only 65,000 parasitised scales from June 28th to October 2nd. Distribution made from some hundreds of small pot plants amounted to about 85,000 parasitised scales from February 2nd to July 24th. There is thus a great advantage in using large pot plants for breeding with a view to distribution.

The white-fly lay their eggs on the lowest leaves of the plant, and when the scales from them turn black, showing the presence of the parasite, the branches are removed, packed into boxes and sent out to nurserymen with the following printed instructions:—

“EXPERIMENTAL AND RESEARCH STATION, CHESHUNT, HERTS.

Instructions for Distribution of White Fly Parasite.

The Tomato shoots enclosed in the box have upon them scales of White Fly containing the parasite; these scales have turned black.

Small numbers of shoots should be made into a bunch and hung up in glasshouses, remaining there for a period of three weeks. When an average temperature of 70°F. is maintained, black parasitised scales of White Fly may be expected to appear on infested plants from 14 to 21 days after the bunches have been hung in the houses.

In cases of severe infestation of White Fly, when immediate control measures are called for, the houses may be fumigated with sodium cyanide and sulphuric acid, the amount of cyanide per 1,000 cubic feet recommended being one-eighth ounce with one-half fluid ounce 33% sulphuric acid. The latter amount will kill the majority of adult flies, and will not harm the parasite, leaving the young stages of the fly alive for the parasite to breed in. Five ounces of tetrachlorethane or fumigant containing this liquid, will have the same effect.

Paraffin emulsion sprays are liable to kill the parasite. The parasite being averse to leaves of Tobacco, Datura, Eucalyptus, Bouvardia and Abutilon, a high percentage of parasitism cannot be expected upon these plants."

Three sizes of collapsible cardboard boxes, respectively 14 in. × 14 in. × 14 in., 14 in. × 9 in. × 6 in., and 10 in. × 6 in. × 4 in. in size were used for packing the tomato shoots upon which the parasitised scales were situated. Of these, the second size was found to be by far the most convenient for despatch through the post, as they would contain some 40 shoots with 2,000 parasitised scales upon them. For local distribution some 10,000 parasitised scales could be packed into the largest size box.

Results of Distribution.

In September printed cards were sent out to all institutions and growers to whom parasites had been sent from February to the end of July, in order to obtain information as to the effect, if any, of the parasite in controlling white-fly.

The following Table gives the number of recipients and the result obtained for each month in England and Wales :—

Month Received.	Recipients Reporting.		
	Complete Control.	Partial Control.	No Effect.
February ...	2	1	0
March	2	2	0
April	0	3	1
May	13	8	0
June	11	10	1
July	0	12	1
TOTAL ...	28	36	3

It will be noted that no case of complete control was reported from consignments of the parasite received after the end of June. The figures for April do not necessarily indicate that this is a bad month for making distribution, as the number of consignments sent out was very small; the large number of parasites sent out were available only at the very end of that month, and were actually received by growers in May.

Two of the three cases in which no effect was obtained, showing that the parasite did not become established, refer to localities in the north of England; very small consignments only were received by the growers in question. In the other case, the parasite was re-distributed from a single consignment, and it is probable that the parasites emerged from the scales before receipt.

From evidence at hand, it appears that improvement may in future be obtained by distributing the parasite to larger commercial nurseries in May and early June, and to owners of small glasshouses from February to April.

Observations made on several commercial nurseries upon which partial control was reported showed, in August and September, a very high percentage of parasitism in houses where the state of repair was good, and a low percentage (about 30%) in leaky houses. The parasite is not inclined to lay its eggs in the scales in draughty situations.

The continuous warm weather during the summer was especially favourable to the parasite. As reported in 1927, the parasite again travelled great distances from nursery to nursery late in the season, but it was not recorded as doing so earlier than July.

At the Experimental Station the white-fly was kept in check throughout the season, and for the first time since 1920 it was unnecessary to resort to any form of fumigation. This is the more remarkable, as the block of tomato houses were especially subject to infestation through the large numbers of flies bred in the parasite houses. In August, large numbers of white-fly scales appeared upon the foliage of the tomato plants in the houses used for testing the effects of temperature upon growth. These at once became parasitised to an extent of over 90%, and the lower foliage of the plants was used for distribution of the parasite to growers, the supply available in the parasite house being low at the time.

It remains to be seen if destruction by the parasite of vast numbers of white-fly scales during the season will have an effect upon the incidence of the pest in glasshouses next year.

Overwintering Habits.

Through the kindness of the Parasite Laboratory at Farnham Royal, parasitised scales of white-fly were kept at a low constant temperature during the winter. The adult parasites failed to emerge from these when taken out of cold storage in the spring. There is no evidence to show that the parasite can over-winter in this country, so that distributions will have to be made annually to nurseries upon which only partial control can at present be obtained, from stock bred in artificial heat during the winter.

3. Other Glasshouse Pests.

E. R. SPEYER.

(a) *Chrysanthemum Midge*

(*Diarthronomyia hypogæa* F. Low.).

Through the energetic co-operation of *Chrysanthemum* growers in the Lea Valley in carrying out recommendations made in December, 1927, especially in relation to the removal and destruction of all young growth from the base of the plants (*see* Annual Report, 1927, p. 78) prior to the taking of cuttings, the *Chrysanthemum* midge has not made a reappearance upon any nursery in this district. It is therefore extremely probable that the insect has been stamped out entirely upon these nurseries, and re-invasion, except through the purchase of infected stock from other districts is more than unlikely.

(b) *Chrysanthemum Capsid*

(*Lygus pratensis* L.).

Early in July, the notorious pest, locally known as " Bishop's Fly " made its appearance on *Chrysanthemums* especially the variety Cheshunt White, in the open at the Experimental Station. The plants were thoroughly dusted with ordinary flowers of sulphur and the treatment appeared to have considerable effect in keeping the insect from feeding upon the foliage and stems. Plants untreated showed far more distortion of growth at the end of August than those which had been dusted. Flowers of sulphur have been used for the control of a closely allied Capsid (*Lygus elisus vae* Duzen) on cotton in the United States, but the immediate action of the sulphur upon the latter insect as described by E. A. McGregor (U.S. Dept. of Agriculture Technical Bull. 4, July, 1927) did not take place in the case of the *Chrysanthemum* Capsid.

The long spell of dry weather was especially favourable for the action upon the bug, and the maintenance of the sulphur upon the plants treated but the suggested remedy is worth further trial upon commercial nurseries.

(c) Wire-worm (*Agnotes* Sp.).

When young tomato plants were planted in new ground in the parasite breeding house at the Experimental Station in February, many plants were immediately destroyed by wireworm. It had been observed previously by the Director that plants in soil treated with Cheshunt Compound developed normally while those in untreated soil were badly attacked by wireworm, and it was suggested that ammonium carbonate was the cause of this immunity. Therefore after removing the plants powdered ammonium carbonate was broadcast upon the soil surface at the rate of 4 oz. per sq. yd. : this was well watered in.

Pot-plants placed in the house up to 3 days after treatment of the soil were scorched by ammonia gas, but on the fourth day it was found possible to replant in the ground.

No plant was lost afterwards from wireworm attack, and though the insect was found sparingly in the soil at the end of the season, the number of stems bored by it was insignificant.

Trials are in progress upon commercial nurseries to test out the efficiency of carbonate of ammonia in the prevention of wire-worm attack.

5. Chemical Investigations.

O. OWEN.

1. Soil Analysis, etc.

The usual number of soils and several samples of water supplies have been examined during the year. It may be of interest to note that some of the soils from the Nazeing area are distinctly poor and "hungry." Even after cultivation they show comparatively low analytical data. The texture of the soils is satisfactory and the fact that good crops are being obtained shews that, with careful treatment, the poorness of the soil is of little disadvantage.

A case of interest to those choosing new sites for nurseries near the sea was dealt with in August. Plants growing in a nursery were shewing undesirable symptoms and examination of the soil shewed that a sample of the top six inches contained 0.29 per cent. of sodium chloride. The second six inches contained 0.24 per cent. The examination of some of the soil in the Station tomato houses shewed that the concentration was of the order of 0.012 per cent. Two samples of water from the nursery in question shewed contents of 11.99 gms., and 12.07 gms. per litre of sodium chloride respectively. It was clear that the chloride content of the water supply was responsible for the salt in the soil in the houses since a sample of soil from adjoining open land receiving rain contained only 0.0029 per cent. sodium chloride. There appears to be no cheap and safe method of removing sodium chloride from this soil except by flooding with water. In this particular case the water itself is contaminated and a change of soil is the only alternative. In time, the new soil will become contaminated and it, in its turn, must be replaced. Growers in similar circumstances would be well advised to consult an analyst before purchasing.

2. The Amount of Nitrate Nitrogen in some of the Experimental Plots.

In the Annual Report for 1927 the variations and the amount of nitrate nitrogen in the soil of some of the experimental plots were reported. This work was continued during the winter 1927-28 and until May, 1928. The plots examined and their manurial treatment were as follows :—

K2B	Unmanured.		
K1B	Double complete artificials.		
K5B	Complete artificials.		
K6B	"	"	less phosphates.
K7B	"	"	" nitrogen.
K8B	"	"	" potash,

All these plots are in the oldest block of tomato houses at the Station and have been cropped continuously since 1915.

In the newer block of tomato houses (erected at the end of 1922) the following plots were examined :—

N1B Manured and cropped since 1923.

N4B Manured and fallow since 1923.

Q4B Unmanured and fallow since 1923.

Samples were taken to a depth of five or six inches from six or eight places in a plot and mixed. As far as possible they were taken once a week from each plot from November, 1927, till May, 1928. Immediately after sampling the soil was passed through a 3 mm. sieve. After thorough mixing, 200 gms. or 250 gms.—the quantity depended on the sample to be analysed—were extracted with warm distilled water. Aliquot parts of the extract were boiled gently for six hours with dilute alkaline permanganate to remove ammonia and organic matter. Finally the nitrate was reduced and estimated by the Devada method. Concurrently the moisture in each sample was determined and all results were calculated for the soil dried at 100°C.

The results are given in tables 1 and 2, and shewn graphically in figures 1 to 4.

An important point which appears to be general for these plots is that the nitrate value shows a tendency to fall at the end of April or in May. This holds good for all the plots irrespective of manuring or the presence of a growing crop. In every case there is a value at this period which is practically the lowest recorded in each plot. It is important to note that there are considerable variations in values during the period under consideration, but this particular fall is outstanding in each case.

Table 1.

House K. Nitrate Nitrogen in parts per million of Oven Dried Soil.

Date.	K2B. Un- manured.	K1B. Double C.A.	K5B. Complete A.	K6B. No Phosphates.	K7B. No Nitrogen.	K8B. No Potash.
1927.						
Nov. 11	—	—	—	—	—	20·96
" 16	13·31	—	—	—	—	—
" 21	—	—	—	—	11·28	17·29
" 22	—	—	16·05	12·89	—	—
" 24	11·16	35·51	—	—	—	—
" 28	—	—	—	—	8·18	27·27
" 29	—	—	10·52	19·39	—	—
" 30	12·98	45·71	—	—	—	—

Table 1 (continued).

Date.	K2B. Un- manured.	K1B. Double C.A.	K5B. Complete A.	K6B. No Phosphates.	K7B. No Nitrogen.	K8B. No Potash.
1927.						
Dec. 5	—	—	—	—	—	—
" 6	—	—	10.94	31.27	8.60	7.17
" 7	14.68	57.84	—	—	—	—
" 12	—	—	—	—	12.37	18.65
" 13	—	—	10.68	14.37	—	—
" 14	—	35.80	—	—	—	—
" 16	—	—	—	—	13.59	36.51
" 19	—	—	10.56	14.26	—	—
" 20	18.13	17.60	—	—	—	—
1928.						
Jan. 2	—	—	—	—	—	—
" 3	—	—	—	—	10.86	26.01
" 4	15.91	107.2	19.67	10.86	—	—
" 9	—	—	—	—	—	—
" 11	—	—	—	—	15.17	13.70
" 12	21.47	50.93	20.48	27.83	—	—
" 16	—	—	—	—	—	—
" 17	—	—	—	—	17.24	23.24
" 18	16.72	81.83	22.77	24.94	—	—
" 24	—	—	—	—	—	—
" 25	—	—	—	—	16.50	36.56
" 26	20.13	105.0	20.84	40.29	—	—
" 31	—	—	—	—	—	—
Feb. 1	—	—	—	—	17.56	26.18
" 2	20.51	120.6	24.69	28.06	—	—
" 6	—	—	—	—	—	—
" 7	—	—	—	—	19.95	37.95
" 8	20.46	132.5	26.85	29.18	—	—
" 13	—	—	—	—	—	—
" 14	—	—	—	—	24.66	40.24
" 15	22.45	114.4	42.38	29.16	—	—
" 20	—	—	—	—	—	—
" 21	—	—	—	—	23.12	50.64
" 22	22.49	103.8	26.70	34.18	—	—
" 27	—	—	—	—	—	—
" 28	—	—	—	—	27.14	45.03
" 29	27.32	116.6	34.51	37.96	—	—
Mar. 12	—	—	—	—	—	—
" 13	26.87	98.42	—	34.07	36.55	51.89
" 19	—	—	41.96	—	—	—
" 20	34.25	86.78	—	67.11	37.79	44.75
" 26	—	—	50.81	—	—	—
" 27	43.47	136.8	—	65.64	41.39	60.24
April 10	—	—	50.51	—	—	—
" 11	37.81	71.03	—	45.58	38.15	54.44
" 16	—	—	46.46	—	—	—
" 17	54.43	22.71	—	56.67	28.61	75.60
" 23	—	—	20.97	—	—	—
" 24	28.55	143.5	—	31.14	9.96	48.06
" 30	—	—	19.00	—	—	—
May 1	35.06	72.18	—	34.98	9.19	29.22
" 7	—	—	17.3	—	—	—
" 8	7.16	33.82	4.25	4.95	12.44	16.00

Table 2.

Houses N and Q. Nitrate Nitrogen in parts per million of Oven Dried Soil.

Date.	N1B, Cropped.	N4B, Fallow.	Q4B Unmanured, Fallow.
1927.			
Nov. 17 ...	31.26	59.85	107.8
" 25 ...	66.82	66.22	136.6
Dec. 1 ...	116.7	119.6	91.4
" 8 ...	50.99	104.0	78.09
" 15 ...	50.32	54.34	—
1928.			
Jan. 5 ...	66.04	64.24	84.41
" 13 ...	61.51	62.67	79.31
" 19 ...	57.28	88.24	68.42
" 27 ...	52.66	79.16	44.35
Feb. 3 ...	79.75	75.15	99.72
" 9 ...	51.44	93.42	105.0
" 16 ...	69.95	88.12	60.85
" 23 ...	80.71	85.61	105.5
Mar. 1 ...	107.5	125.4	155.0
" 14 ...	128.0	100.5	98.31
" 21 ...	131.6	135.9	101.3
" 28 ...	121.9	87.52	70.79
April 2 ...	95.76	97.18	107.4
" 19 ...	66.67	39.36	51.9
" 25 ...	79.23	51.12	58.48
May 2 ...	114.1	115.6	69.65
" 9 ...	47.5	129.0	18.23
" 15 ...	—	117.6	24.09
" 21 ...	—	92.56	21.85

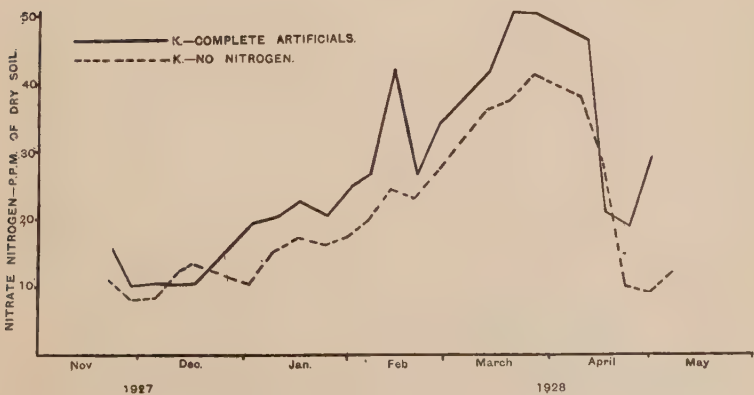
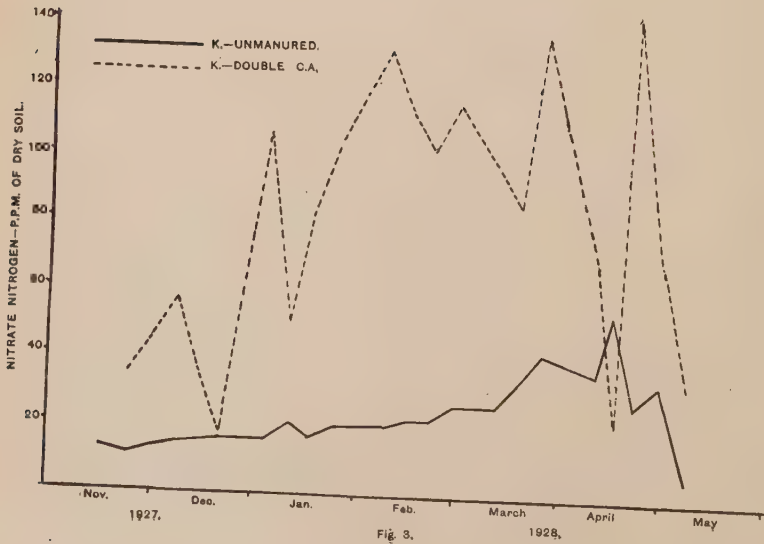
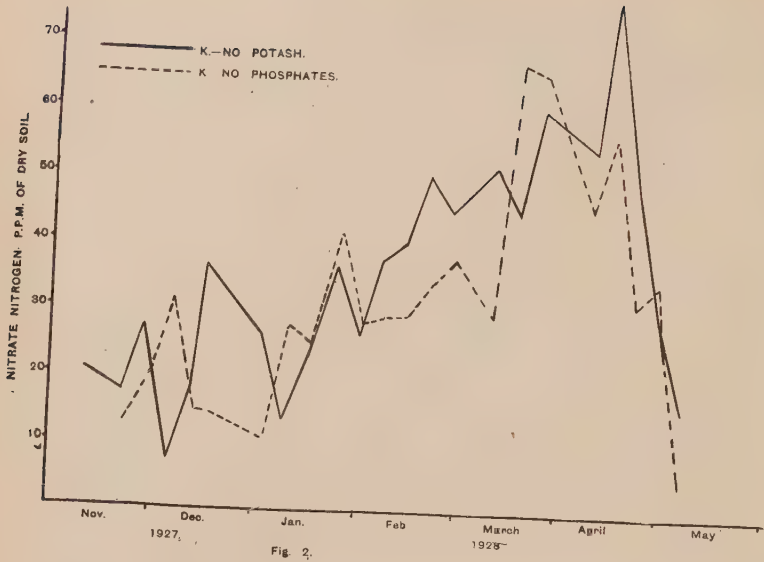


Fig. 1.



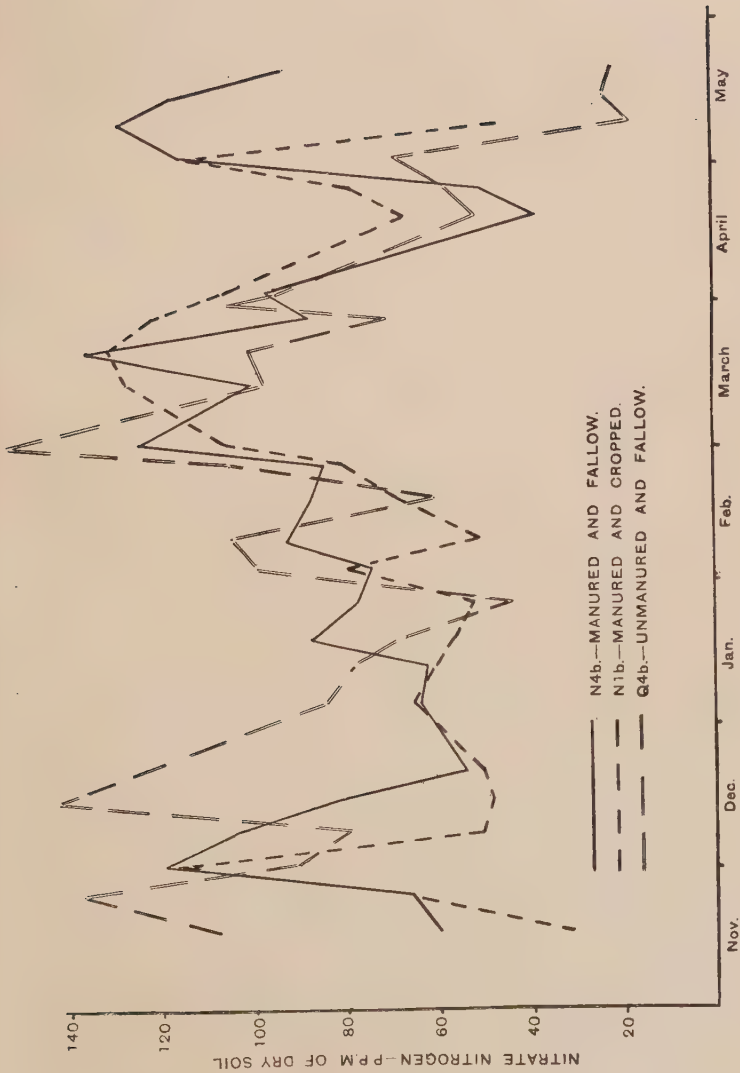


Fig 4.

A similar result was obtained in the early part of 1927 and, in the last report, it was suggested that the fall was due to the leaching following the first watering. Until it is possible to analyse the leachings from a plot it will not be possible to decide this point satisfactorily. It is significant, however, that the fall in values shewn in the present results does occur after watering. It appears safe to conclude that the first heavy watering contributes to this nitrate depression and, if leaching is not the factor responsible, there must be some factor which operates at this period and possibly, is induced by watering.

Another point of interest is suggested by the curves for the K plots. The curves for K7B, K1B, K5B all shew a gradual rise in values from November onwards. In the other three plots in this house the variations are more pronounced, but the main trend of the curves is the same. The young plants were planted here on March 6th, but this does not appear to have any effect on the tendency of the nitrate content to increase. It is concluded that accumulation of nitrates commences in November and continues, despite planting, until about April. Soon after this comes the big fall, consequent upon watering. The steady accumulation of nitrates appears to have taken place in this house K irrespective of the manurial treatment. In the unmanured plot K2B, where the variations are relatively slight there was a steady rise from 11.16 p.p.m. on November 24th, 1927, to 43.47 p.p.m. on March 27th, 1928. The curves for the complete artificial and no nitrogen plot in fig. 1 shewed a more decided increase, and it is remarkable that the difference between the curves should be so small. In both K1B and K7B the only source of nitrogen is that originally present in the virgin turf when the houses were built. It is remarkable that there should be still a sufficient residuum of nitrogen to give such an accumulation of nitrate as K7B shews.

The curves for the double complete artificials, no potash and no phosphate plots, shew that the variations in these three soils are considerable. Why this should be so is problematical, but the high values for the double complete artificials plot are probably due to the high amount of nitrogen added to this plot each year. That this particular plot does not give an exceptional crop, despite its relatively high nitrate content, suggests that nitrogen is unlikely to be a factor limiting the crop on this particular plot.

The plots N and Q in the younger block of houses shew, as last year, very considerable variations in the nitrate content and these are such as to mask any trend that the values might shew. They agree, however, in that in each case the values commence to fall early in May.

In figures 5 and 6 are plotted the moisture content and temperature at time of sampling as well as the nitrate for the plots K5B—complete artificials and N4B—manured and fallow, respectively. These curves do not admit of very definite



Fig. 5.

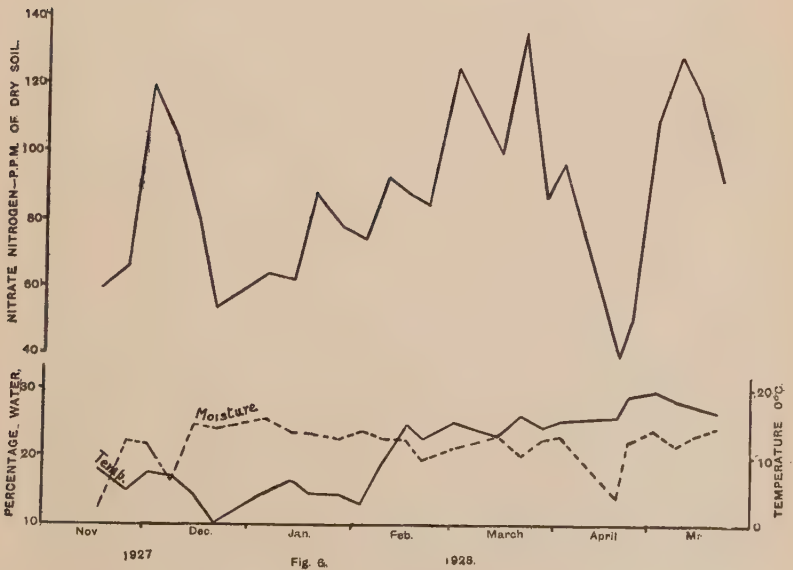


Fig. 6.

conclusions, but they may indicate that the water content of the soil varies inversely as the nitrate content whilst the variation between nitrate concentration and temperature vary directly.

Determinations were also made from March, 1928, to May, 1928, of the nitrate nitrogen of four plots in house H. The four plots receiving the same manurial treatment were watered by different methods, namely :—

- H1 Plants in trenches and
- H2 Slow constant supply.
- H7 Ordinary watering.
- H8 Subterranean watering.

In H1 the nitrate values followed the usual trend, that is to say, a high value was shewn in March and then followed the usual fluctuations with low values during May. In H2, the values were generally much higher and shewed wider variations than those in H1, but finally fell to similar values during May. H7 and H8 shewed very high values and considerable variations, and from the middle of April till the middle of May the values lay close together, both falling considerably towards the middle of May. An interesting point on these results was the fact that the two plots, H7 and H8, in the west side of the house shewed values considerably higher than those for the two plots, H1 and H2, on the east side of the house.

The main conclusions to be drawn from these observations are, firstly, that there is a steady accumulation of nitrate nitrogen in these soils from November until April or May. This process of accumulation is unaffected by planting or manurial treatment. Secondly, there is a decided fall in the nitrate content of all soils at the end of April or during May. This fall occurs soon after watering has begun. Thirdly the higher the total nitrate content of the soil the larger are the variations from week to week.

3. Chlorates in a Tomato Soil.

In this report for 1927 facts were adduced to shew that the poisonous effects of a soil were due to the presence of chlorates. This point has been examined further. In the course of attempts to estimate the chlorates it was evident that the soil under examination, and others too, contained small amounts of iodates. These probably had their origin in Chili salt petre. This salt, which is a constituent of some mixed manures and is sometimes used itself, contains most of its iodine as iodate. In time, measurable amounts of iodate would be added to soils in this way. This iodate is liable to interfere with chlorate determinations and eventually it was decided to determine the iodate as chlorates, together with the chlorate, and correct the results so obtained by determining the iodate separately. These estimations were made by the usual quantitative methods.

The concentration of chlorate in the soil was found to vary considerably with different samples and the following values were obtained in some of the analyses :—0·0153 and 0·0189 per cent. sodium chlorate calculated on oven-dried soil. As already reported the symptoms produced in plants growing in the poisoned soil were exactly reproduced in plants growing in normal soil to which had been added sodium or potassium chlorates. From comparison of plants growing in soil containing equivalent amounts of these two salts it appeared that the sodium salt was more potent than the potassium salt.

It is interesting to note that small concentrations of potassium perchlorate in soil produce a peculiar mottle in tomato plants, and in time, brown lesions on the stems, but these symptoms are distinct from those produced by the chlorates. Of interest, too, are the effects of bromates and bromides. Both these compounds added to soil as their potassium or sodium salts, appear to stimulate the growth of young tomato plants when added in very low concentrations. At higher concentrations this effect disappears, and the tomato plant appears able to tolerate quite appreciable amounts of these salts.

The origin of the chlorates in the soil is still problematical. All the artificial manures used at the Station have been examined, but chlorates appeared to be absent. In this connection, it must be noted that all these manures are of a high grade of purity and examination of manures of inferior quality may yield different results.

4. The Effect of Copper on Tomato Plants at various stages of growth.

A number of experiments have been carried out in extension of work described in the Annual Report for 1924. The work was arranged to examine the effect of copper in the form of sulphate and, as Cheshunt Compound in

- (1) Germination of tomato seed.
- (2) Young plants.
- (3) Mature plants.

It was found repeatedly that the effect copper may have on plants is influenced considerably by weather conditions, *i.e.*, by temperature, humidity and light, so that the conclusions reached must be considered as indicative rather than absolute.

Effect of Copper Sulphate on Germination.

Seeds of the varieties, Manx Marvel, Comet and E.S.1 were used at different times, and there appeared to be little difference in the results for the different varieties,

Up to a concentration of 0.3 per cent. of copper in the soil the percentage germination is unaffected and the rate of germination may be accelerated. This beneficial effect, however, is more than nullified by the fact that, when real growth begins even low concentrations have a deleterious effect on the seedlings. Despite an advantage gained in the early stages of development, treated seedlings are not as healthy as those untreated and, even if potted in clean soil at an early stage, they prove no better than those grown in clean soil throughout.

When copper sulphate is added to the soil, a concentration of 0.28 to 0.3 per cent. of copper is the limit beyond which germination is definitely depressed.

When copper is added as Cheshunt Compound, any injury to seedlings or deleterious effect in germination is always considerably less than the effect caused by the same amount of copper as sulphate.

The Effects on Young Tomato Plants.

Any injury to young plants and due to the injudicious use of Cheshunt Compound may manifest itself at two stages. It may happen either when the plants are potted or after planting out. If used as directed in the Report for 1921 (p. 38) the maximum amount of copper added to a plant in a 60 pot would not exceed 0.02 gms. of copper. On a number of occasions this amount has been exceeded considerably with no untoward effects on the plant.

The maximum amount of Cheshunt Compound solution added to the soil round a plant after planting would be 2 pints per annum. Assuming that this is applied for ten consecutive years and that *none* is washed out, the accumulation over this period would amount to 25 gallons of solution, that is, 1.370 gms. of copper. Assuming it to be distributed in 10 lbs. of soil, the concentration of copper is of the order of 0.035 per cent. In repeated experiments we have found that up to 0.07 per cent. of copper as Cheshunt Compound in soil is entirely innocuous and at much higher concentrations the effects are negligible.

The Effects on Mature Plants.

For these experiments plants were grown in large pots and stopped at four trusses. Various concentrations of copper were used as sulphate and as Cheshunt Compound respectively. The first conclusion reached was that the copper sulphate is more potent than Cheshunt Compound at the same concentration of copper. There was little effect on the crop even with concentrations of 0.19 per cent. of copper as sulphate. The number of seed per fruit was unaffected, and there was no effect on the ability of the seeds to germinate. Seed from treated plants, however, gave a proportion of unsatisfactory seedlings.

Treatment of Poisoned Soil.

The grower's most important concern is the treatment of soil which may have become poisoned, and to be able to detect the symptoms, which are more or less similar to those produced by most poisons. In seedlings the stems become blue or violet in colour and the cotyledons a dark green. The rough leaves are dark green on making their appearance, but soon become a pale yellow, and the veins shew in bold relief. These symptoms are accompanied by stunted growth and sometimes by distortion.

In young pot plants severe poisoning is accompanied by shrivelling of the lower leaves; brown streaks on the stems and the leaves at the tips become yellow on the upper surface, and often blue or violet on the under side. These plants do not necessarily die, but little or no apparent growth is made and, when the lower leaves have fallen off, the plants consist of vertical stems, each surmounted by a tuft of stunted leaves.

With large plants the effects are not so definite and, even with comparatively large amounts of copper no striking differences are noticeable between treated and control plants.

Washing with Water.

Where the concentration of copper in the soil is low much benefit is derived from heavy watering. When the concentration is so high as to cause immediate (*i.e.*, within 2 days) injury no amount of water appears to remove the copper completely. For instance, in one series of experiments, some pots of soil which was highly toxic, were watered daily for three weeks so that water flowed freely through the drainage holes on each occasion. At the end of this time the leachings, after concentration, shewed none of the usual qualitative tests for copper. On planting in this soil the symptoms did not appear immediately, but were quite definite at the end of eight days.

The Effect of Lime.

Hydrated lime has been found to give satisfactory results when applied to poisoned soil. In mild cases of poisoning a light dressing at the soil surface is usually sufficient to encourage normal growth. With more severe cases it is necessary to mix the lime with the soil and water the whole heavily, and, when the mixing is really thorough, the amount of copper which is rendered innocuous is surprising.

The Effect of Manures.

Stable manure, sulphate of ammonia, sulphate of potash and basic slag have all been found of some benefit. None of these, however, is as effective as hydrated lime. Of the four, application of sulphate of ammonia, followed by watering is the most satisfactory.

The Effect of Soiling.

On many occasions plants shewing the typical symptoms have made good recovery when one or two inches of "clean" soil have been added round the stems. Even in seed boxes where there has been little room for the addition of such soil seedlings have made excellent recovery after this treatment. This confirms the view that copper, although causing the plant very severe injury, often does so without actually killing it, and the plant can live for appreciable periods in the presence of a toxic concentration. When more favourable root conditions prevail, as when new soil is added, new roots are formed and new growth is made.

6. Temperature Investigations.

W. CORBETT AND W. F. BEWLEY.

Preliminary work on the temperature requirements of the tomato under glasshouse conditions was begun during the current season. The work included both soil and air temperatures.

Air Temperature.

To ascertain the best air temperature for the tomato crop an experiment was conducted in tomato house 6, which is divided into six chambers each 14 ft. square. This house was originally designed for temperature investigations and arranged so that temperatures of 90°F., 82°F., 74°F., 66°F., 58°F., and 50°F. can be maintained in the different chambers when the outside temperature is 32°F.

It was intended in the present experiment to maintain minimum temperatures of 70°F. in chambers Nos. 1 and 2, 65°F. in chambers Nos. 3 and 4, 60°F. in chamber No. 5, and 55°F. in chamber No. 6. To this end automatic temperature controls were fitted to the heating system (Drayton A. M. Regulators), the thermostat being placed in the centre of the chamber. These regulators proved accurate to within $\pm 2^\circ\text{F}$.

It is very difficult to maintain a constant minimum temperature in a glasshouse owing to the great loss of heat by radiation through the glass and the variation in outside conditions. Heavy rain alone can depress the temperature inside the chambers some 7°F., and some variation from the desired temperatures were expected.

Plants of variety E.S.1 were stood out, 56 in each chamber, on February 9th, and were planted on February 17th. The following table shows the weights of crops received from the different chambers.

Table 1.

Chamber.	POUNDS PER PLANT.							Tons per Acre.
	May.	June.	July.	August.	Sept.	October.	TOTAL.	
1	·45	·92	1·28	·60	·36	·03	3·84	29·18
2	·36	1·76	1·21	·53	·45	·35	4·66	35·31
3	·56	1·83	1·06	·84	·75	·73	5·80	44·08
4	·83	1·93	1·00	1·08	·72	·53	6·09	46·27
5	·07	1·55	1·89	·62	·59	·17	4·89	37·18
6	·14	1·69	1·48	·71	·83	·18	5·03	38·22

Within ten days from planting there was a noticeable difference between the plants in the different chambers. In chambers Nos. 1 and 2, the plants were 10-14 inches high; they were thin, weak, and of a pale unhealthy colour. Plants in Nos. 3 and 4 chambers were much stronger in appearance; were 9-12 inches high, but inclined towards "softness." The plants in No. 5 chamber presented the best appearance; they were about 9 inches in height, of a healthy dark green colour and were inclined to be on the "hard" side. The plants in No. 6 chamber were very short, having hardly moved, the stems and veins were purple in colour and they generally presented the appearance of being cold.

Later the differences in appearance were not so marked, particularly between chambers Nos. 3, 4 and 5. The plants in chambers Nos. 1 and 2, however, never presented a good appearance; they remained weak, and the flowers of all the first trusses, and of some of the second trusses failed to set. No. 1 chamber experienced a bad attack of "Stripe" disease, and liberal dressings of sulphate of potash had to be given to save the plants. This may account for the small crop received from this chamber. Plants in chambers 3 and 4 presented the best appearance throughout the season and, as will be seen from Table 1, gave the best crop. The plants in chamber No. 5 were always good plants with a healthy appearance. Those plants in chamber No. 6 after suffering from a severe attack of Oedema looked almost as good as the plants in chamber No. 5.

The attack of Oedema is probably explained by the fact that the automatic temperature regulator had to be disconnected in this chamber, and so the temperature increased to such an extent that the plants previously retarded were suddenly forced into activity. The leaf surface was insufficient to cope with the increased activity of the roots and water was expelled through the typical swellings associated with Oedema.

As will be seen from Table 1 the best crop was obtained from chambers Nos. 3 and 4, the average crop from these chambers being 21% greater than that from chamber No. 5, and 28% greater than the crop obtained in No. 2 chamber.

For a short period at the beginning of the season detailed temperature records were taken, but it was found impossible to continue these throughout the season.

Six's thermometers were hung on the four walls of the chambers and a thermograph was placed in the centre, standing on a platform some 2 feet 6 inches above the ground, as near as possible to the thermostat.

The following Table (Table 2) gives the records from three chambers for a week. It will be seen that the temperature on the different walls varies, the west wall being the coldest, and the east

Table 2.

Table shewing differences in temperature in different parts of chambers for a period at the beginning of the experiment.

Date.	Time.	Temperature in °F. Chamber No. 1.					Temperature in °F. Chamber No. 3.					Temperature in °F. Chamber No. 5.				
		South Wall.	West Wall.	North Wall.	East Wall.	Centre	South Wall.	West Wall.	North Wall.	East Wall.	Centre	South Wall.	West Wall.	North Wall.	East Wall.	Centre
Feb. 19	10-10 a.m. ...	84	80	92	81	80	80	76	90	79	85	77	72	86	77	83
"	4-0 p.m. ...	74	72	74	75	76	72	70	72	73	74	74	72	76	76	76
"	10-0 a.m. ...	66	65	69	66	66	62	59	66	62	62	57	56	60	56	58
"	2-30 p.m. ...	64	64	65	65	65	62	60	63	61	61	56	57	60	58	59
"	5-40 p.m. ...	59	59	60	62	61	58	55	58	56	59	53	53	56	54	55
"	9-30 a.m. ...	70	67	67	70	69	66	62	66	64	64	61	59	64	62	62
"	12-45 p.m. ...	75	73	76	76	78	75	74	77	75	76	71	71	78	73	75
"	2-30 p.m. ...	75	75	79	79	77	74	74	76	77	76	78	78	83	80	81
"	6-50 p.m. ...	68	68	68	72	68	66	61	66	66	66	67	66	69	68	68
"	9-30 a.m. ...	74	70	70	73	72	63	59	65	62	62	57	55	59	58	58
"	4-45 p.m. ...	68	66	67	67	68	58	58	60	60	61	58	57	59	61	59
"	9-40 a.m. ...	80	76	77	81	79	69	68	70	69	69	64	62	67	66	65
"	2-30 p.m. ...	79	77	77	80	79	68	66	69	69	68	63	62	64	65	64
"	10-0 a.m. ...	73	69	69	74	71	65	61	64	63	62	60	59	61	62	61
"	5-35 p.m. ...	74	70	70	74	72	63	60	64	64	61	55	55	58	58	56
"	9-30 a.m. ...	74	73	74	76	75	63	59	62	62	61	60	55	59	55	56

wall the warmest wall of the chamber. Another feature is that the temperature in the centre of the chamber is about the average of the temperatures recorded on the walls.

In Table 3, the weekly average mean day and night temperatures are given for chambers Nos. 1, 3 and 5 for the whole period during which the chambers were heated artificially, to illustrate the order of temperature variation.

Table 3.

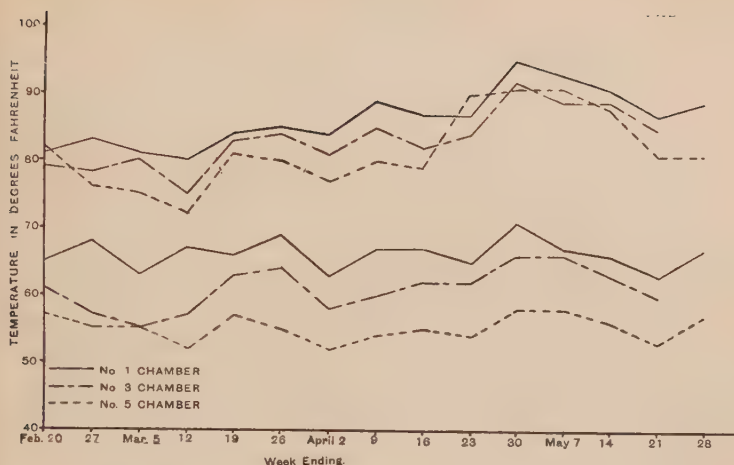
Table giving weekly average mean day and night temperatures °F.

Week Ending	No. 1 Chamber.		No. 3 Chamber.		No. 5 Chamber.	
	Day.	Night.	Day.	Night.	Day.	Night.
Feb. 19	72.5	66.9	67.9	63.4	70.3	62.1
„ 26	74.2	69.3	66.7	61.0	61.5	57.8
Mar. 4	74.9	68.8	68.9	59.4	66.1	56.1
„ 11	73.1	69.9	65.2	59.4	62.5	54.4
„ 18	73.6	72.2	72.2	64.6	68.9	60.6
„ 25	75.1	69.8	73.1	66.2	68.9	57.9
April 1	73.8	66.5	68.1	60.6	66.3	53.1
„ 8	78.2	70.4	73.0	61.5	70.1	55.6
„ 15	74.0	72.0	71.3	63.8	66.8	56.7
„ 22	76.1	68.2	70.6	60.9	66.2	56.1
„ 29	80.1	74.4	79.1	67.3	77.2	61.7
May 6	82.4	72.5	78.9	67.6	76.9	61.9
„ 13	—	—	77.9	64.9	73.9	58.1
„ 20	74.1	64.7	74.1	63.8	67.3	55.9
„ 27	79.0	68.8	—	—	70.9	59.1
June 3	79.2	64.5	79.1	62.6	76.8	57.9
„ *10	74.6	65.0	74.7	64.6	69.7	56.6

* First week after cutting out of artificial heating.

It will be seen from this table that chamber No. 1 alone was maintained within the limits of accuracy of the automatic regulators, and it is probable that the same applies to No. 2 chamber. In chambers Nos. 3 and 5 the temperature was on an average some 3°F. lower than was intended. So instead of the temperatures maintained being 70°F., 65°F., and 60°F., the mean night temperatures were nearer to 70°F., 62°F., and 57°F.

Figure 1 shews graphically the weekly average absolute maximum and absolute minimum temperatures. From an inspection of this figure it will be seen that the graphs of the three chambers, Nos. 1, 3 and 5 follow each other with the exception of the absolute maximum for chamber No. 5, which for the week ending April 23rd, goes higher than the other two chambers.



GRAPH SHOWING WEEKLY AVERAGE ABSOLUTE MAXIMUM AND MINIMUM TEMPERATURES FOR THE PERIOD DURING WHICH THE HOUSE WAS HEATED ARTIFICIALLY

Fig. 1.

Discussion.

It will be seen from results given that a heavier crop was obtained from the plants grown at a mean night temperature of 62-63°F. than from plants grown at mean night temperatures of 70°F. and 57°F., and 58°F. It is probable that plants grown at a mean night temperature of 57-58°F. were stronger than the others and might be expected to resist disease to a greater extent.

It must also be pointed out that these results may not hold good for every year. * It has been shewn that a definite relationship exists between the hours of bright sunshine and crop weight. It therefore seems probable that the temperature also may have a big effect, and it is suggested that with long hours of sunlight, plants may be grown at higher temperatures than may be the case when there is but little sun.

The Effect of Increasing the Soil Temperature.

This experiment was conducted in houses 8 and 9. For the 1927 crop, electric resistance cables, each 328 feet long were buried beneath the soil of four plots at a depth of 16 inches. The cables were so disposed beneath the soil that in general temperatures of 65°F., 70°F., 75°F., and 80°F. could be maintained in each of the four plots respectively, if current was used almost continuously. Table 4 gives the details of these plots, and Figure 2 shews the disposition of the cables beneath the soil.

* Bewley, W. F., "The Influence of Bright Sunshine upon the Tomato under Glass," —Ann. App. Biol., XVI., 281-287, 1929.

Table 4.

Plot.	Area.	Length.	No. of Coils of Cable.	Distance between Coils.	Temp. Maintained.
A	204 sq. ft.	34 ft.	10	6 ins.	65°F.
B	168 "	28 "	12	5 "	70°F.
C	132 "	22 "	16	4 "	75°F.
D	108 "	18 "	18	3½ "	80°F.

In 1927 it was found that after the required temperatures had been obtained by continuous heating for 50 hours, they could be maintained by periodic heating of from 10 to 12 hours, per day. In 1928 a time switch was installed for reasons of economy and the electric current was applied automatically between 10 p.m. and 6 a.m. By this means plots A and B were kept at 67-69°F., plots C and D at 72-74°F., while the control plots were at 60-62°F.

For the present experiment the cables were heating continuously for 54 hours prior to planting. After planting, the required temperatures having been obtained, the time switch was put into use. For the 1927 experiment the plots were not pre-heated.

The plants in all the plots grew away quicker than in the controls and were of a softer type of growth. The following table gives the crop returns from the four heated plots and the control plot for the current season.

Table 5.

Plot.	Temp. °F.	POUNDS PER PLANT.					Total lbs. per Plant.	Tons per Acre.
		June.	July.	August.	September	October.		
A	67-69	1.54	1.57	0.78	0.93	0.05	4.86	36.94
B	"	1.42	1.22	0.65	0.65	0.05	3.92	30.16
C	72-74	1.62	1.70	0.82	0.82	0.07	4.92	37.39
D	"	1.73	1.82	0.70	0.70	0.06	5.03	38.23
Control	60-62	1.35	1.69	0.95	0.95	0.03	4.79	36.40

The slight increase in crop obtained by heating the soil in this way is not beyond the limits of experimental error and does not warrant the use of these heating cables on a commercial scale.

The low yield of 30.16 tons per acre shown by plot B was due to a severe attack of "stripe" disease.

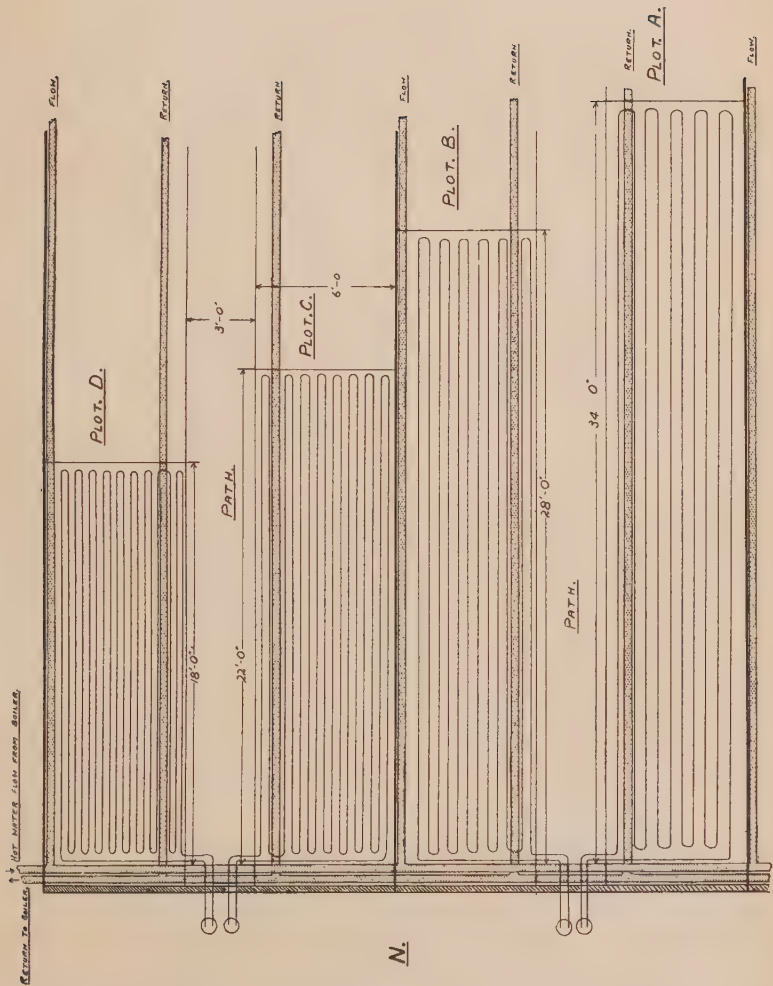


Fig. 2. Diagram Shewing Arrangement of Heating Cables.

APPENDIX A.

Manurial Treatment in the Tomato Experiments.**(1) Lime.**

All Houses except Nos. 10 and 11 received Ground Caustic Lime at the rate of 2 tons per acre.

(2) Stable Manure.

Houses Nos. 2, 5, and 6 received Stable Manure at the rate of 30 tons per acre.

(3) Base Fertilisers.

Houses 2 and 5 received $\frac{3}{4}$ -lb. per sq. yd of the following mixture :—

- 1 part Bone Meal.
- 1 part Bone Flour.
- 1 part Ground Hoof and Horn.
- 1 part Sulphate of Potash.

Houses 7, 8, 9, 11 and 12 received the following per sq. yd. :—

- $\frac{1}{4}$ -lb. Bone Meal.
- $\frac{1}{4}$ -lb. Bone Flour.
- $\frac{1}{4}$ -lb. Sulphate of Potash.

House No. 1, steamed for 1928, received $\frac{1}{4}$ -lb. Sulphate of Potash per sq. yd. only.

(4) Top-dressing.

Houses 1, 2, 5, 7, 8, 9, 11 and 12 received 2-oz per sq. yd. of the following mixture every 14 days at discretion :—

- 3 parts Sulphate of Ammonia.
- 2 parts Dried Blood.
- 7 parts 30% Superphosphate.
- 5 parts Pure dissolved Bones.
- $\frac{1}{2}$ part Bone Flour.
- $2\frac{1}{2}$ parts Sulphate of Potash.

This gave 5% Ammonia, 24% Total Phosphates, 12% Soluble Phosphates, and 7% Potash on examination.

APPENDIX B.

Manures applied in Houses 3 and 4.

House No. 3, steamed for 1928, received no manures at all.

House No. 4.

Plot.	TREATMENT.	Base Manure in Lbs. per sq. yd.						† Top-dressing in Lbs. per sq. yd.			
		Stable Manure.	Basic Slag.	Bone Meal.	Bone Flour.	Ground Hoofs.	Sulphate of Potash.	Superphosphate.	Sulph. of Ammonia.	Nitrate of Soda.	Sulph. of Potash.
*1	Double Complete Artificials (Formula I.) ...	—	0.8	—	—	—	0.2	1.0	0.4	0.4	0.4
2	Unmanured	—	—	—	—	—	—	—	—	—	—
3	Complete Artificials (Formula I.) with Standard	14	0.4	0.5	0.5	0.5	0.6	0.5	0.2	0.2	0.2
4	Complete Artificials (Formula I.) with dung ...	7	0.4	—	—	—	0.1	0.5	0.2	0.2	0.2
5	Complete Artificials (Formula I.)... ..	—	0.4	—	—	—	0.1	0.5	0.2	0.2	0.2
6	Complete Artificials (Formula I.) without Phosphates	—	—	—	—	—	0.1	—	0.2	0.2	0.2
7	Complete Artificials (Formula I.) without Nitrogen	—	0.4	—	—	—	0.1	0.5	—	—	0.2
8	Complete Artificials (Formula I.) without Potash	—	0.4	—	—	—	—	0.5	0.2	0.2	—

* Half of each plot received 14-lbs. Grass Cuttings per sq. yd. in addition.

† The Top-dressing was applied in eight equal instalments.

APPENDIX C.
Dates of Cultural Operations during 1927—1928.

Crop.	Sown.	Potted into 60's.	Potted into 32's.	Planted out in borders.	First Mulching.	First Top Dressing.	First Fruit Picked.	Last Fruit Picked.
Cucumbers ...	Dec. 21 1927	Dec. 30 1927	Jan. 21 1928	Feb. 12 1928	Mar. 13 1928	—	Mar. 21 1928	Sept. 28 1928
Tomatoes ...	Dec. 21 1927	Jan. 23 1928	—	Mar. 4 1928	—	May 8 1928	May 18 1928	Oct. 19 1928

APPENDIX D.

Meteorological Records, 1928

	Air Temperatures				Grass Temp.		Rainfall				Soil Temperatures		Hygrometer			Bright* Sunshine	Baro- meter			
	Mean	Absolute		Av. Min.	Absolute Min.		Total Pre- cipitation	No. of Days	Biggest Fall			Depres. of Wet Bulb	Relative Humidity %	Dew Point						
		Max.	Min.		Date	Temp.									Date					
																°F.	°F.	°F.	°F.	°F.
January	46	31	53	24th	26	27th	—	Ins. 3.28	22	.72	2nd	°F. 40.5	41.5	°F. 2	84	36	Ins. 29.838			
February	50	36	60	{ 26th 28th	29	19th	—	1.69	11	.35	2nd	41.4	41.9	47	3	79	41	—	30.026	
March	54.8	37.5	71	5th	27	11th	—	1.68	15	.44	8th	42.5	43.1	47.5	4	75	40	—	29.712	
April	61.1	—	72	27th	—	—	—	.87	14	.29	1st	46.7	46.6	49.9	4	74	42	—	29.784	
May	61.5	42.2	76	{ 28th 29th 30th	33	14th	—	1.55	12	.32	17th	52.7	52.4	53.9	4	76	46	142.7	29.867	
June	67.6	47.2	79	13th	37	{ 10th 16th	32	2.63	16	.70	13th	60.2	58.5	60.6	5	73	51	196.9	29.923	
July	73.5	52.3	89	15th	45	28th	39	28th	1.55	7	.57	65.7	63.8	67.4	7	64	57	258.8	30.005	
August	71.4	50.1	82	11th	42	{ 4th 6th 18th 30th	37	{ 4th 6th	1.87	15	.63	63.1	62.3	64.3	4	82	58	163.0	29.889	
September	68.8	44.0	85	8th	34	19th	31	{ 19th 20th 26th 30th	.68	4	.42	59.3	62.9	57.7	3	83	53	180.4	30.072	
October	59.8	41.7	67	{ 7th 8th	26	13th	22	13th	3.47	21	.75	51.9	53.2	53.5	2	84	48	90.9	29.814	
November	49.5	36.8	59	13th	29	{ 4th 28th 29th	26	9th	2.53	17	.51	47.4	48.7	46.8	2	86	43	49.6	1.65	29.741
December	44.0	31.1	57	1st	18	8th	14.5	8th	2.62	18	.47	41.25	43.1	37.1	1	91	35	42.1	1.40	29.984

* The Campbell-Stokes sunshine recorder was installed on May 4th.

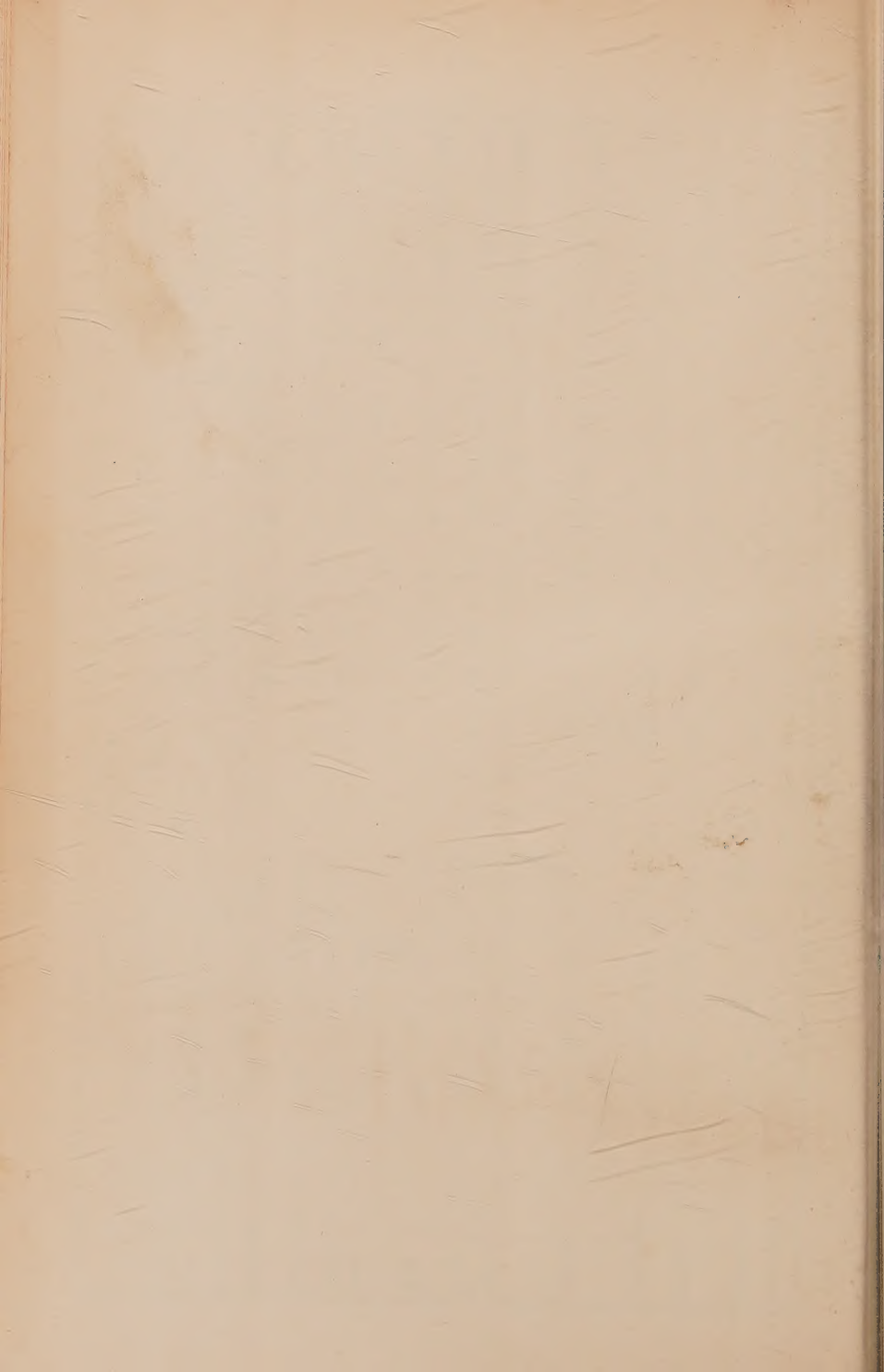


DIAGRAM SHOWING ARRANGEMENT OF EXPERIMENTAL PLOTS, 1928.

